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ALASKAN REMOTE SITE EVALUATION FOR FUEL CELL ENERGY SYSTEMS

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
Twelve Minimally Attended Radar (MAR) sites in Alaska were evaluated to characterize their diesel engine energy system and to determine their thermal and electrical energy consumption. Due to insufficient available data from the sites, a complete data acquisition system was installed at the Fort Yukon MAR site. An economic model was developed to evaluate the life cycle costs of remote site energy systems. A sample run of the model was made based on the most accurate data available for a generic MAR site.
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ALASKAN REMOTE SITE EVALUATION FOR FUEL CELL ENERGY SYSTEMS — STUDY GIST

Principal Findings

(1) There are twelve remote Minimally Attended Radar (MAR) sites located throughout Alaska which have diesel engine cogeneration systems to supply electricity and heat.

(2) Limited thermal and electrical energy consumption was obtained for the MAR sites.

(3) A remotely accessed site data monitoring system was successfully installed at the Ft. Yukon MAR site.

(4) An economic model was developed to evaluate the life cycle cost of remote site energy systems, including diesel engine and fuel cell systems.

Main Assumptions

(1) Fuel cell power plants will be designed to be compatible with the electrical and thermal loads at the MAR sites.

(2) The data acquisition system installed at Ft. Yukon will provide data necessary to evaluate diesel engines and produce an actual life cycle cost for the Ft. Yukon site.

Principal Limitations

(1) The energy consumption data presently available from the MAR sites was much less complete than expected. Much data was lost due to the transitional stage of several sites from Long Range Radar Stations (LRRS) to MAR facilities.

(2) Energy parameters from the sites are often estimated by site operators due to lack of instrumentation.

(3) The Ft. Yukon site electrical and thermal loads are adequately monitored. However, to adequately characterize the existing diesel generators, additional thermal and electrical instrumentation will have to be installed.

(4) The generic remote site test case for the economic model requires more precise input data.

Scope of the Study

The scope of the study was to evaluate the energy systems of remote Alaskan radar sites and develop a life cycle cost model to support the Air Force's Program to evaluate and demonstrate the feasibility of fuel cell power plants in these applications.

Study Objectives

(1) Characterize the design, installation, operation and maintenance of the MAR site energy systems.

(2) Collect existing MAR site thermal and electric energy consumption data.

(3) Install a data acquisition system (DAS) at one site to collect detailed site energy load data.

(4) Develop a remote site energy system life cycle cost model.

Basic Approach

The energy usage at the MAR sites was characterized by visiting several sites, obtaining site construction and operating data and collecting the limited energy usage data that was available. A complete data acquisition system was installed at the Ft. Yukon MAR site to collect detailed energy usage data. A life cycle cost economic model was prepared and exercised for a generic remote site diesel engine system based on the best available data.

Reason for Performing the Study

To provide a remote site requirements base and an economic evaluation model to support the Air Force's Remote Site Fuel Cell Development Program's objective of demonstrating logistically fueled fuel cell power plants at remote Alaskan sites in the early 1990's.

Study Sponsor

Belvoir Research Development and Engineering Center.

Comments and Questions

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Actions Taken as a Result of Findings

(1) Install DAS equipment at an additional remote site to substantiate the data from the existing site, to better characterize the diesel engines and provide better inputs for the life cycle cost of the total energy system of remote sites.

(2) Prepare the life cycle cost of several specific remote site energy systems based on the additional data.

(3) Evaluate the thermal and electrical characteristics of the MAR sites for an additional year during which much more reliable data will be available because very few sites will be in a transitional stage.

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EXECUTIVE SUMMARY

The objective of the Air Force Remote Site Fuel Cell Development Program is to demonstrate logistic fueled fuel cell power plants at a remote site in Alaska in the early 1990's.

In support of this goal, Science Applications International Corporation (SAIC) has performed the following four tasks.

- o Characterize the design, installation, operation and maintenance of the Minimally Attended Radar (MAR) site energy systems
- o Collect existing MAR site thermal and electric energy consumption data
- o Install a data acquisition system (DAS) at one site to collect detailed site energy load data
- o Develop a remote site energy system life cycle cost model

SITE ENERGY SYSTEM DESCRIPTIONS

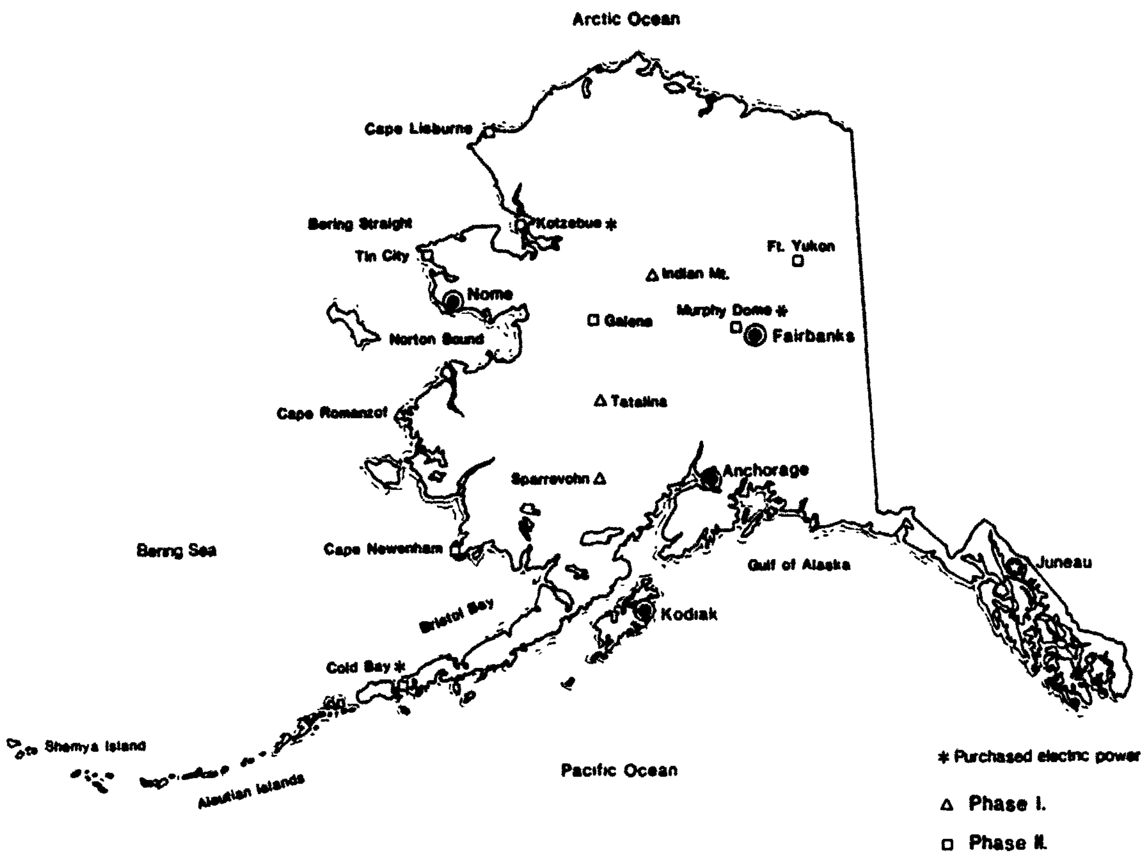
During 1984 and 1985, the remote radar sites were undergoing transition from the Long Range Radar Stations (LRRS) built in the early 1950s to the MAR facilities which incorporate system consolidation and modernization using less manpower, less energy and having reduced operational requirements.

There are a total of twelve MAR sites, four Phase I, four Phase IIA, and four Phase IIB. The four Phase I sites were constructed from identical designs. They consist of two domed structures (residential and industrial) which can house up to 18 site personnel. The energy system consists of four 175 kW diesel engines used in a cogeneration mode to supply electricity and heat in addition to two 1.4 MMBtuh diesel fueled boilers sized to supply the entire thermal load in an emergency. The normal operating mode for the diesel generators is two parallel generators equally sharing the load, one on hot standby and one in reserve.

The four Phase IIA MAR facilities are very similar in design concept except they do not use domed structures. They have four 250 kW generators rather than 175 kW, and there are minor differences between the structures and energy systems at the four sites.

The four Phase IIB sites will no longer be remote sites but will be served by nearby electric grids. Therefore, no attempt has been made to collect further data concerning these sites.

Alaska Remote Radar Sites



REMOTE SITE ENERGY USE PATTERNS

The thermal and electric energy usage of the remote sites was obtained, summarized and analyzed for 1984 and 1985. The analysis includes comparisons of fuel consumptions electricity production, operation parameters, costs and degree days. The data for the LRRS consist of gross monthly oil consumption and corresponding degree days. The annual total kWh usage and Btus consumed were also obtained. Data from the MAR facilities consists of total monthly oil consumption, degree days and kWhs generated. Heat consumption data was not available. The following table is a summary of the remote site energy data collected for 1984. Almost all of the data is based on LRRS facility energy systems which were quite different from one another. Section 3.1 provides more detail regarding the LRRS 1984 energy data

Energy Usage Characteristics at LRRS Facilities - 1984

Site	Electric and Thermal Usage		Electric and Thermal Capacity Factors		Thermal to Electric Ratio
	MWH	MBTU	% Electric	% Thermal	T/E
1) Indian Mountain	3,706	20,887	47.0	16.5	1.65
2) Fort Yukon	2,845	**	18.0	—	—
3) Tin City	2,731	23,730	31.2	20.7	2.54
4) Cape Lisburne	3,215	21,092	26.2	16.0	1.92
5) Cold Bay	3,233	**	30.8	—	—
6) Tatalina	3,050	19,436	34.8	52.7	1.87
7) Sparrevohn	3,860	10,583	24.5	13.6	.80
8) Murphy Dome	*	32,119	—	28.5	—
9) Kotzebue	2,573	**	32.6	—	—
10) Cape Newenham*	2,831	22,294	43.0	29.1	2.31
11) Cape Romanzof	3,055	23,210	34.9	24.2	2.22

* Purchased Power is wheeled through local Air Force Base
** Heat recovery equipment used exclusively at these sites
* Data for Cape Newenham is MAR Site Data from 2/84-12/84

Energy data reports were received from the MAR sites during 1985. Engine, boiler and combined fuel consumption for the Phase I and IIA sites were entered into a computer data base. Calculations based on this data and

several assumptions provided operational performance parameters as summarized below. A glossary of terms used in the data base are included in Appendix D.

	Average Monthly Degree Days	Average Monthly kWh Generation	Maximum Peak Demand (kW)	Power Plant Capacity Factor	Average Monthly Site Load Factor	Electrical Efficiency
Phase I						
Indian Mountain (MAR)	989	195151	---	.38	---	.34
Sparrevohn (MAR)	1019	167269	390	.33	.59	.34
Tatalina (MAR)	575	196197	---	.38	---	.36
Cape Romanzof (MAR)	980	240824	510	.47	.64	.37
Phase IIA						
Cape Newenham (MAR)	928	178740	350	.24	.70	.29
Ft. Yukon (MAR)	721	87498	240	.12	.45	.35
Ft. Yukon (LRRS)	1615	199603	465	.14	.60	.29
Cape Lisburne (LRRS)	1373	246028	612	.19	.55	.30
Tin City (LRRS)	1267	222271	443	.28	.69	.28

The power plant capacity factors were relatively low. This was expected because of the remoteness of the sites and the criticality of consistent power supply. The site electrical consumption patterns are all similar. Some variances exist due to different climatic conditions, site operating procedures and general site characteristics.

The site load factors show considerable variance from site to site. It is assumed that severe weather fluctuations caused the low load factors.

The electrical efficiencies of the MAR site diesel generators was relatively high except for Cape Newenham which has Caterpillar diesel generators rather than Cummins. It is not presently known why this discrepancy exists.

Predominantly because 1985 was a year of conversion from LRRS status to MAR sites, the data is not consistent and in some cases not available. Attempts were made to correlate the data and provide better explanations of anomalies in the data at the remote sites. However, it should be considered preliminary. Data collection obtained from actual site monitoring which will be accomplished in a follow-on effort should provide more information for site energy usage evaluation.

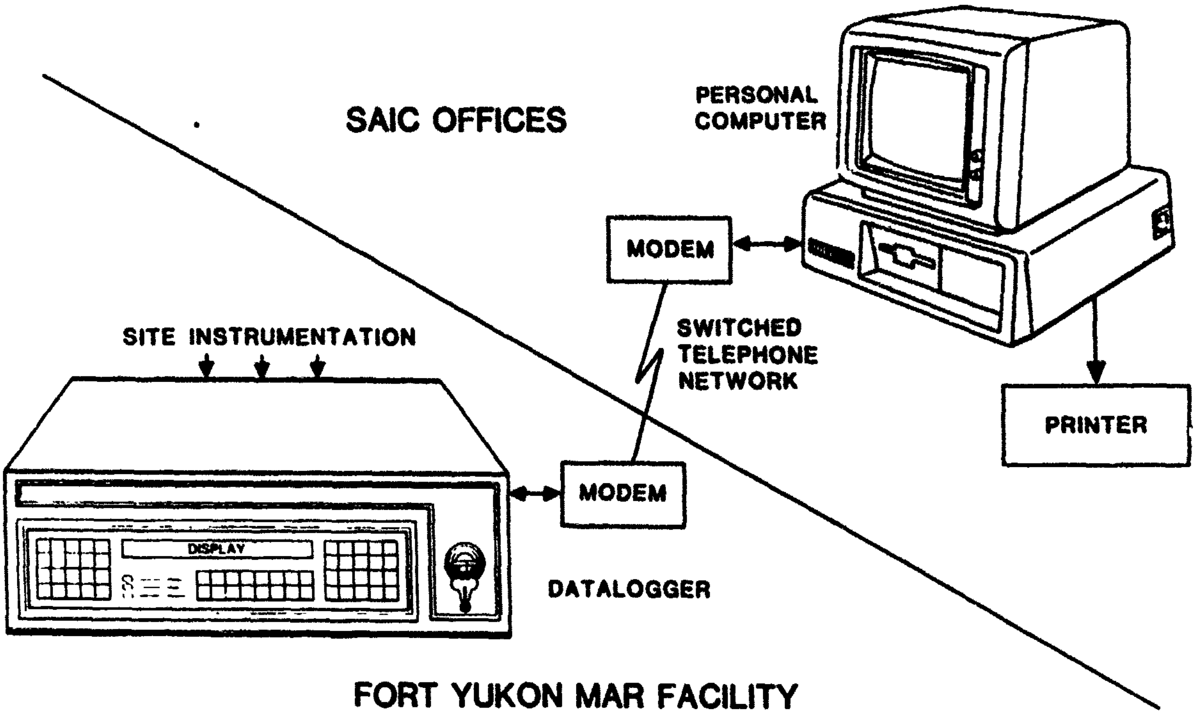
DATA ACQUISITION SYSTEM INSTALLATION

This project originally envisioned installation of limited instrumentation at two MAR sites to collect sample data to verify the energy site data and to fill in gaps of missing data. It became evident that the existing data was insufficient to adequately characterize the remote site energy systems. More detailed data was also required for input to the life cycle cost model. A decision was made to install more instrumentation at one site. Ft. Yukon was chosen as the preferred location for the installation of a remotely accessed DAS because it was accessible from Fairbanks, was a Phase IIA site and represented a severe north Alaskan climate. The DAS consists of sensors, datalogger and modem for data storage and remote telephone access.

The thermal portion of the instrumentation was installed to monitor the heat contribution to the MAR facility by the energy system. Clamp-on RTDs and nonintrusive ultrasonic flow meters were used to obtain data to calculate the thermal energy supplied to the site from the engines, boilers and electric booster heater. The fuel consumption of each of the four engines and the two boilers was measured with 1/2-inch flow meters. The electrical instrumentation consists of current transformers and watt transducers to measure the electrical consumption of the site. A schematic of the location of the instrumentation at the Ft. Yukon energy system is shown in Figure 9.

Data from each sensor is transferred to the memory of the datalogger which is remotely accessed through the modem. The data is transmitted over a telephone line to a personal computer in SAIC's San Diego office where it is stored for further manipulation. A schematic of the DAS is shown in the following figure.

Fort Yukon DAS Schematic



The information obtained at Fort Yukon will be used to determine the technical and economic feasibility of using onsite fuel cell power plants to meet the energy needs of the MAR facilities in place of diesel engines.

ENERGY SYSTEM LIFE CYCLE COST MODEL

An economic model was developed to evaluate the life cycle costs of remote site energy systems. It was developed specifically to analyze diesel engine systems and fuel cell power plants, but could be adapted to analyze other energy systems. The model was exercised to prove its validity with actual data from the remote site systems.

The model is written in FORTRAN and is fully compatible with the IBM Disk Operating System (DOS). It is menu driven to make it easy to use and it is programmed for maximum flexibility. The life cycle cost model is described in Section 5.

A sample run of the life cycle cost model was made based on the most accurate data available for a generic MAR site. Until more dependable input data is available from instrumented sites under a follow-on program, the calculated life cycle cost for a specific remote site energy system is unavailable. However, the available data was used to validate the model and provides the most accurate life cycle cost for a remote site presently obtainable. Fifteen menu pages are used to input data to the program and three output pages show the results. The first page of the output is a summary of the inputs. The generic MAR site test case was based on the inputs shown below.

Life Cycle Cost Analysis Model Input Data

System Description		
Prime mover(s)		Cummins Engine
Number of generators	4	Units
Electrical capacity	250	kW/unit
Boiler thermal capacity	2.8	MMBtu/hr
Boiler efficiency	80	%
Years of analysis	20	Years
Basic fuel cost	1.5	$/gal
Basic oil cost	4.7	$/gal
Installation cost	886000	$
Construction start date		1/1986
On-Line date		1/1987
Inflation Rates		
Consumer Prices	6	%
Fuel Prices	6	%
Electricity	6	%
Discount rate	6	%

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1. INTRODUCTION

The objective of this project is to analyze the feasibility of utilizing onsite fuel cell power plants to meet the electric and thermal energy requirements of remote Minimally Attended Radar stations (MAR) within the Alaskan Air Command. At present, most of these remote sites are powered by diesel engines equipped with heat recovery systems that have been designed as total energy systems. In addition to diesel engines as prime power, the sites have auxiliary diesel-fired boilers and electric emersion heaters to meet water and space heating requirements.

Onsite phosphoric acid fuel cells may offer a number of important advantages over engine generator systems at the MAR facilities. One of the chief advantages of fuel cells is their high energy conversion efficiency, especially at lower power levels. The electric efficiency of fuel cells as compared with other types of electric generating equipment, such as gas turbines, diesel and gasoline engines, is considerably higher at part loads. This fact could have a significant impact on overall system economics as the operating requirement at the MAR sites is to limit operation of the diesel engines to approximately 80 percent capacity or less.

Additional incentives for using fuel cells in remote applications include system modularity, which allows a closer match with facility electrical and thermal requirements, and the ability to respond to varying load demands of greater than 50 percent rated output within 0.1 seconds. Other advantages include the potential for reduced maintenance requirements due to fewer moving parts and reduced noise and pollution levels that could translate into lowered costs due to less stringent requirements for noise attenuation and power plant isolation.

To meet the project objective, relevant standards and other information pertaining to the design, installation, operation, and maintenance of power systems for MAR facilities within the Alaskan Air Command have been

identified and studied. Analysis of available energy data from those sites not yet converted to MAR status has also been undertaken. The historical data consists of monthly kilowatt-hour use, monthly fuel consumption for the engine generator sets and total facility fuel consumption. The preconversion Long Range Radar Stations (LRRS) have been in a transitional phase to MAR status at the twelve sites. Therefore, complete sets of data for all sites are not yet available. Additional information will become available as more LRRSs are converted to MAR status and normal operation begins.

Information from twelve MAR facilities, pertaining to future planning and design criteria, has been obtained. At present, the MAR facilities are in a transitional phase from Korean War vintage construction and operation (most sites initiated operation between 1950 and 1953) to system consolidation and modernization designed to reduce energy consumption, manpower, and operational requirements.

The twelve sites have been divided into two construction phases by the Alaska District, Army Corps of Engineers. The Phase I sites (shown in Figure 1) are as follows:

- Indian Mountain
- Sparrevohn
- Tatalina
- Cape Romanzof

The Phase I sites are similar in structure and consist of two domed buildings connected by a second story bridge. The total energy system design at these sites is comprised of four 210 kW diesel engine generators (derated to 175 kW) that provide electricity and by-product heat for the facility.

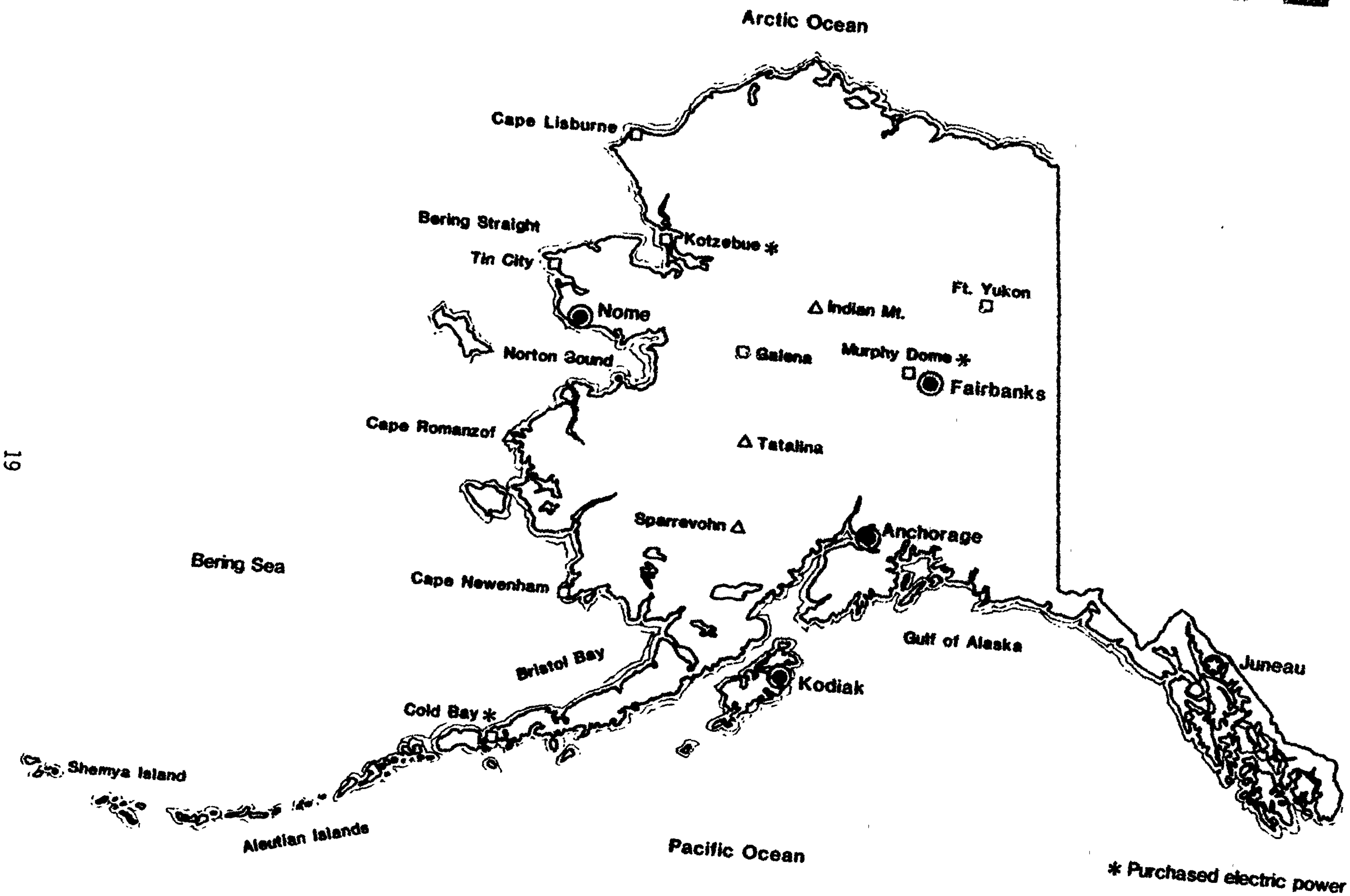

Figure 1. Alaska Remote Radar Sites

The Phase II sites (Figure 1) consist of the following facilities:

- Cape Newenham
- Ft. Yukon
- Cape Lisburne
- Tin City
- Murphy Dome
- Kotzebue
- Galena
- Cold Bay

Four of these sites, (Phase IIB; Cold Bay, Murphy Dome, Kotzebue and Galena) will provide their own heat but will obtain power through local utility or Air Force base generators. The four remaining sites, (Phase IIA; Ft. Yukon, Tin City, Cape Lisburne, and Cape Newenham) will each have as prime power, four 250 kW diesel engine generators with heat recovery equipment to provide heat and electricity to the facilities. Unlike the Phase I sites, these four sites vary in construction and size.

As shown in Figure 1, the locations of the remote radar sites vary from the northern most site at Cape Lisburne to the southern most site near the Aleutian Chain at Cold Bay. The environmental conditions do vary significantly based on location of the facility. Table 1 provides site elevations indicating the bottom camp elevation where the power plant is located and top camp elevation for the radar facility location, recorded temperature extremes for each site location, and the heating degree days for 1984 at each site.

This report is divided into five sections. Section 2 provides detailed descriptions of the MAR facilities and their energy production systems. Section 3 describes and analyzes the energy use patterns at the remote sites. Section 4 documents the design and installation of a DAS to measure energy consumption at the Ft. Yukon MAR facility. Section 5 discusses an economic model which was developed to predict the costs associated with providing energy at a MAR facility with diesel engines and/or onsite fuel cell power plants.

Table 1. MAR Sites Environmental Conditions

SITE	ELEVATIONS (Ft.)	TEMPERATURE EXTREMES ^{o}F		HEATING DEGREE DAYS $65^{o}F$ BASE
	Bottom Camp/Top Camp	Maximum	Minimum	
Indian Mountain	935/4195	88	−65	16,100
Tatalina	1340/3250	88	−45	13,200
Sparrevohn	1570/3225	85	−50	12,000
Cape Romanzof	1550/2340	78	−26	13,500
Fort Yukon	435/435	97	−69	13,600
Cape Newenham	700/2000	75	−25	10,300
Tin City	270/2275	75	−44	17,000
Cape Lisburne	55/1585	73	−47	17,800
Murphy Dome	2900/2900	93	−62	13,200
Kotzebue	145/145	85	−52	16,800
Cold Bay	40/40	78	−9	9,000
Galena	144/144	92	−62	14,500

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2. MINIMALLY ATTENDED RADAR STATION DESCRIPTIONS

The twelve original LRRS facilities have been undergoing consolidation and modernization, including the removal of barracks-type facilities and out-moded radar systems that require more than 50 personnel per site to operate and maintain. The new MAR facilities can be operated by three to nine personnel depending on site characteristics. The MAR sites have been divided into two construction categories by the Alaska District, Army Corps of Engineers: the four Phase I facilities that consist of two bridge-connected geodesic dome structures with primary power provided by four 210 kW diesel engines (derated to 175 kW); and the eight Phase II facilities. The latter can be further divided into two additional categories, facilities with prime power generating capabilities (four 250 kW diesel engines with heat recovery equipment), and facilities that provide their own heat, purchase outside power and use diesel engines for emergency power only. The construction status of each of the twelve remote radar sites is shown in Table 2. The transitional period is the time during which both the old LRRS facilities were operational and the new MAR facilities were being checked out.

2.1 PHASE I MAR FACILITIES

The Phase I MAR facilities (Indian Mountain, Tatalina, Sparrevohn and Cape Romanzof) have been standardized in construction and energy system equipment and consist of two new domed structures connected by a second story bridge. The residential dome typically houses nine permanent site personnel and has a maximum capacity to house eighteen. The industrial dome contains the prime power generating and auxiliary heating equipment. Table 3 shows the generating capabilities, housing capacities and resupply methods of the decommissioned facilities vs. the capabilities of the new Phase I MAR Sites.

Table 2. Construction Time Table for Remote Radar Sites

Site	LRRS Termination Date	LRRS to MAR Period Transitional Period	MAR Site Conversion Completion Date
Phase I			
Indian Mountain	Before 10/84	Before 10/84-10/84	11/84
Sparrevohn	10/84	08/84-10/84	11/84
Tatalina	03/85	12/84-03/85	04/85
Cape Romanzof	01/85	02/85-07/85	08/85
Phase IIA			
Cape Newenham	02/84	02/84	02/84
Ft. Yukon	04/85	04/85	04/85
Tin City	Summer 1986		Summer 1986
Cape Lisburne	Summer 1986		Summer 1986

Table 3. Comparison of Phase I. MAR Facilities and Decommissioned Facilities

SITE / REQUIREMENT	DECOMMISSIONED FACILITIES: INDIAN MOUNTAIN	TATALINA	SPARREVOHN	CAPE ROMANZOF	NEW PHASE I. FACILITIES: INDIAN MOUNTAIN, TATALINA SPARREVOHN, CAPE ROMANZOF
POWER	Primary - 10 Cummins 100kW Units Lower Camp Portable - 1 MB-18 W 30kW Unit Emergency - 1 Continental 15kW Unit Standby - 4 Cummins 200kW Units Upper Camp	Primary - 11 Cummins 100kW Units Portable - 1 MB-18 W 30kW Unit Emergency - 1 GM 100kW Unit	Primary - 9 Cummins 200kW Units Emergency - 4 Cummins 100kW Units Upper Camp	Primary - 11 Cummins 100kW Units Portable - 1 MB 18W 30kW Unit Emergency - 1 GMC 100kW Unit	Primary - 4 Cummins 210kW Units Derated to 175kW with Heat Recovery Emergency - 1 MB-18 W 30kW Unit
HEAT	3 - Pacific Steel, Firetube HRT (Horizontal Return Tube) 74HP each 2 - Birchfield, Firetube HRT, 100HP each 1 - National Radiator, Cast Iron Boiler, 297 MBTUH 2 - Hot Air Furnaces	3 - Cyclotherm Corp Firetube Package, Int. FB, 125HP each 2 - Hot Air Furnaces	2 - Pacific Steel Firetube HRT, 70Hp each 2 - Fitzgibbons Firetube HRT, HW 42HP each 1 - Kewanee, 42HP 12 - Hot Air Furnaces	3 - Kewanee, Firetube portable, FB 109HP ea. 3 - Hot Air Furnaces, 225-350 MBH	2 - Ajax Boilers 1,750,000 Input 1,400,000 Output 4 - 24kW Hot Water Emersion Coils
FACILITIES	Permanent 56 Semi-Permanent 6 Temporary 20	Permanent 49 Semi-Permanent 8 Temporary 16	Permanent 46 Semi-Permanent 17 Temporary 11	Permanent 43 Semi-Permanent 19 Temporary 3	2 Permanent Geodesic Domes
HOUSING CAPACITY	142	164	140	131	18
RESUPPLY METHODS	Air - Air Force, Charter	Water - Barge Air - Air Force, Charter	Air - Air Force, Charter	Water - Barge Air - Air Force, Charter	Water - Barge Air - Air Force, Charter Maximum Aircraft - C130 Payload - 35,000 lbs. Cargo Hold - L-60', W-12' Cargo Door - W-12', H-8'6"

Note: All Generating Systems Are Fueled By Diesel Fuel Arctic (DFA)

2.1.1 Engine Room Description

The industrial domes of the Phase I MAR facilities are similar in construction and design. The first floor of the industrial dome consists of a vehicle repair and storage room that occupies approximately two-thirds of the first floor area. The prime power room that houses the four engine generator sets, two boilers and a 500 gallon electric immersion glycol-water heater, plus ancillary equipment, occupies the remaining one-third and contains approximately 2,500 ft^2 of floor area.

Access to the prime power room from the vehicle/storage room for equipment installation and removal is through two separated 9' x 9' sound rated panels. A three ton overhead crane is available in the vehicle area and a two ton overhead crane is used in the prime power room to move equipment when required. The concrete engine pads are 5'-3" x 13'-11" and the engines themselves are isolated on steel frames that measure 2'-6" x 11'-3". The skid mounted weights of the 175 kW and 250 kW Cummins engines were 7400 lbs dry for each. Residential and industrial dome floor plans are provided in Appendix A.

2.1.2 General System Description

Based on calculated loads made from worst winter conditions with all four 24 kW electric immersion heaters on, the generator plant has been sized to be capable of producing 700 kW of prime power.

The plant consists of four 210 kW diesel engine generators rated at:

175 kW continuous,
218.75 KVA continuous,
0.8 power factor
1200 RPM, 120/208V, 3Ø, 4-wire, 60-Hz

Figure 2 presents the pertinent engine operating data supplied by the engine manufacturer for this system and the calculated overall electrical efficiency, based on the higher heating value (HHV) of No. 2 diesel fuel, where

$$\text{Efficiency} = \frac{\text{Kilowatts} \times 3{,}412 \frac{\text{BTU}}{\text{kWh}}}{\text{Fuel} \frac{\text{Gal}}{\text{hr}} \times 138{,}700 \frac{\text{BTU}}{\text{Gal}}}$$

With No. 1 diesel fuel the engine is derated 3 percent.

Based on analysis of operating data, the actual engine efficiencies appear to be meeting the specification as noted in Figure 2. However, some of the data is questionable and will be verified by a follow-on effort to collect and evaluate actual data at two MAR sites.

The generator operating principle that has been developed for these sites states that one or two of the four units operate continuously at 80 percent of capacity (175 kW) with a 20 percent reserve for sudden load increases. The second or third unit would operate in a standby mode (180°F glycol-water solution circulated through the engine loop), and the fourth unit is typically down for maintenance or in reserve.

The actual operating scenario for February 1985 at Sparrevohn, which is a Phase I site, is as follows:

Peak demand of 390 kW required three generators on line;
Minimum demand of 230 kW required two generators on line.

During the peak demand period, all four 24 kW heating elements of the electric immersion tank were on, and one boiler was activated. This is typical for winter conditions. As stated above with the engine/generator-sets sharing load equally during peak demand, three units were each at 130 kW or 75 percent

ENGINE DATA

Make: Cummins

Model: KTA-1150-GC1 (1200 RPM)

			Fuel		
Load	Kilowatts	HP	#/Hr.	G/Hr.	kWh/G.
100%	210	300	103	14.5	14.52
75%	157	224	78	10.98	14.34
50%	105	149	54	7.67	13.68

PHYSICAL CHARACTERISTICS OF DIESEL FUELS

	Weight Fuel		Heat Value		Sp Gravity at 60°F. 15.5°C	Gravity
	LB/Gal	kg/l	BTU/Gal	kJ/l		Deg. API
#1	6.79	.814	133,900	37,545	.816	42
#2	7.29	.874	138,700	39,524	.876	30

Calculated Electrical Efficiency (HHV):

Load	Efficiency
100%	35.6
75%	35.2
50%	33.7

Electric Generator Power Factor at Full Load: .80

Figure 2. Engine Data for Phase I. Sites

capacity. During the minimum demand period two generators were loaded at 115 kW or 65 percent capacity. The average demand for the month was 280 kW.

In April 1985, operation at Sparrevohn showed a 350 kW peak load with three generators on-line. Each generator in this case was loaded to 66 percent capacity. Average demand for the month was 265 kW.

From this preliminary site energy consumption data it appears that the engines are seldom loaded to their rated capacity and at times operate below 70 percent capacity.

2.1.3 Generator Heat Recovery, Cooling and Heating System

Each engine has a separate exhaust header system that allows for individual operation and the by-product heat recovered from the engines (exhaust and water jacket) is the primary energy source for tempered ventilation air and domestic hot water. Heat is recovered by transfer to an ethylene glycol-water mixture (60 percent - 40 percent) at approximately 180°F. Supplemental diesel-fired backup boilers (two each @ 1.4 MM BTU/hr) are used to fulfill heating requirements during periods of peak heating and low electrical usage. In the event of prime power outage, the boilers are capable of meeting all of the facility's heating requirements.

The electric immersion boiler has four 24 kW heating elements that provide additional electrical loading during periods of high thermal requirement and low electrical usage. This allows operation of the combined electrical power generation/heat recovery system in its optimum efficiency range. In accordance with Corps of Engineers' requirements, the control of the electric boiler is manual instead of automatic. During periods of high electrical use and low heating requirements, the engines are cooled using a dual radiator system.

The estimated heat recovery potential for one 210 kW engine generator loaded at 175 kW load is as follows:

Exhaust gas heat recovered	(at approximately 1,000°F)	-	350,000 BTU/hr
Jacket water heat recovered	(at approximately 210°F)	-	543,000 BTU/hr
Engine radiant heat	(indoor installation)	-	97,440 BTU/hr
Generator radiant heat	(indoor installation)	-	42,900 BTU/hr
	Total	-	1,033,340 BTU/hr

Figure 3 is a schematic of the basic engine heat exchanger plan showing the coolant flow through the remote heat loop to heating loads during periods of heat requirement, and the coolant flow through the three way AMOT thermostat valve to the radiator during periods of reduced heating requirements. Figure 4 is the flow diagram for the engine generator heat recovery and facility heating systems. The diagram indicates the redundancy and back-up system requirements for electrical and thermal energy production at the MAR facility. This has been previously discussed in Section 2.

Each engine generator set is equipped with a combination exhaust heat recovery silencer and heat exchanger that allows for individual operation. The engine cooling water is circulated through the engine pump and through the engine AMOT valve that controls the engine running temperature by mixing different temperature glycol-water solutions. When the engine temperature rises to where it needs cooling, the AMOT valve opens allowing hot glycol solution to enter the exhaust heat recovery loop while the engine pump is pulling in cooler glycol-water solution from the return line. The glycol-water solution in the heat recovery loop is circulated by the engine cooling pump. The solution is pumped through the heat recovery silencer into the tube-and-shell heat exchanger, which is used to transfer the recovered engine heat to the building heating loop. After the engine glycol-water solution passes through the heat exchanger, the system AMOT valve directs the cooling water, depending on its temperature, either back to the engine or to the remote radiators for further cooling before returning to the engine cooling and heat recovery loop.

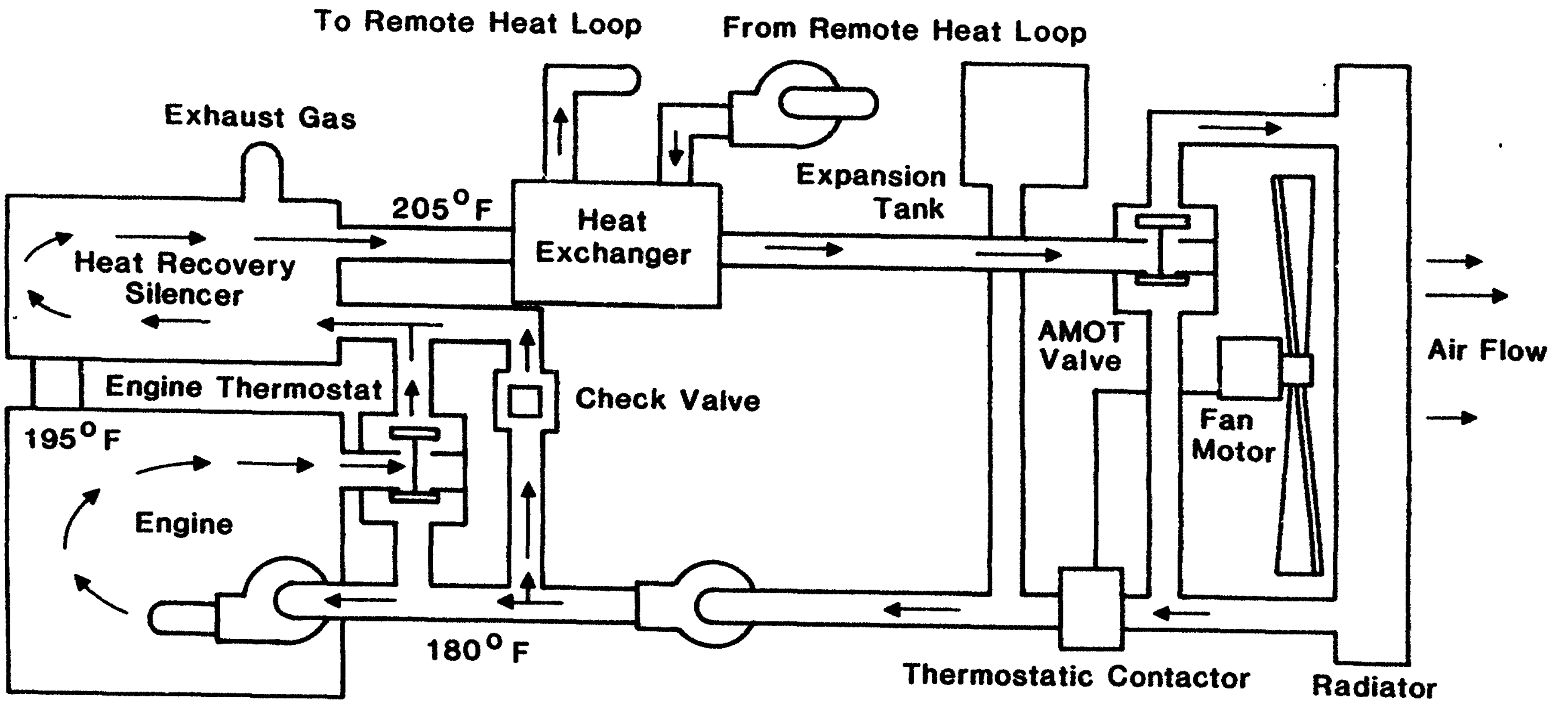

Figure 3. Basic Heat Exchanger Plan

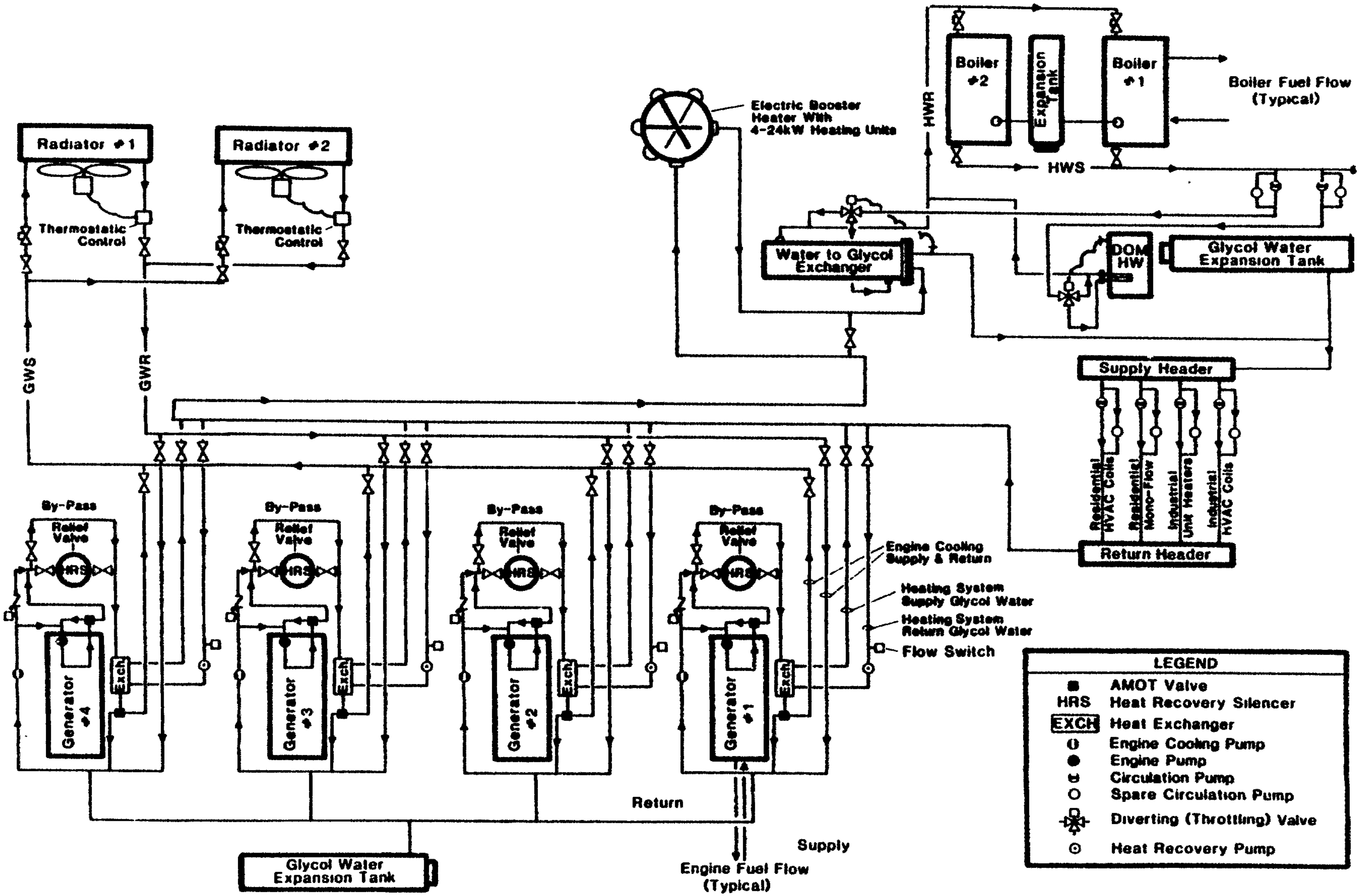

Figure 4. System Flow Diagram

2.2 PHASE IIA MAR FACILITIES

2.2.1 Engine Room Description

An attempt to standardize Phase IIA MAR facilities began with Ft. Yukon and includes Cape Lisburne, Cape Newenham and Tin City. Each facility power system consists of four 250 kW diesel engines and a heat recovery system with auxiliary heating equipment similar to the Phase I scheme.

Ft. Yukon and Cape Lisburne are similar in construction in that they each consist of two connected buildings, residential and industrial. Ft. Yukon can house eighteen personnel and Cape Lisburne is a site adaptation of the residential building at Ft. Yukon. An additional requirement for Cape Lisburne is a weather cab above the ridge line of the residential building which allows for the inclusion of two more sleeping areas. The Tin City project provides for the consolidation of all support functions into one building for housing and power generation while the Cape Newenham Project consists of the remodel of two separate buildings and provisions for one new building. One variation in the equipment schedule is that three 150hp (382 MBtuh) boilers at Cape Lisburne have been retained in lieu of the newer boilers. Table 4 compares the decommissioned LRRS facilities to MAR facilities. The Phase IIA facilities are not domed structures but are composite adaptations of existing structures and are of type "N" construction (AFM88-15). Structural elevations of these facilities are shown in Appendix A.

A typical Phase IIA prime power room houses four 250 kW engine generator sets, two 2.25MM BTU input/1.8MM BTU output diesel boilers, a 500 gallon electric immersion glycol heater with four 24 kW elements, a 420-gallon domestic hot water generator and ancillary equipment. The engine generator specifications are summarized in Figure 5 and efficiencies are based on No. 2 diesel fuel (HHV). Access to the prime power room for equipment removal can be accomplished from the outside of the structure through two 7'6"W x 8'3"H doors. A two ton overhead crane is available to facilitate equipment moving.

Table 4. Comparison of Phase IIA. MAR Facilities and Decommissioned Facilities

SITE / REQUIREMENT	DECOMMISSIONED FACILITIES: FORT YUKON	DECOMMISSIONED FACILITIES: CAPE LISBURNE	DECOMMISSIONED FACILITIES: CAPE NEWENHAM	DECOMMISSIONED FACILITIES: TIN CITY	NEW PHASE IIA. FACILITIES: FORT YUKON	NEW PHASE IIA. FACILITIES: CAPE NEWENHAM	NEW PHASE IIA. FACILITIES: CAPE LISBURNE	NEW PHASE IIA. FACILITIES: TIN CITY
POWER	Primary - 10 Cummins 200kW Units	Primary - 5 Chicago Pheumatic 350kW Units Portable - 1 MB 18kW Unit Emergency - 1 GMC 100kW Unit Top Camp	Primary - 11 Cummins 100kW Units Portable - 1 MB-18 w 30kW Unit Emergency - 1 GMC 100kW Unit	Primary - 11 Cummins 100kW Units Portable - 1 MB-18 W 60kW Unit Emergency - 1 GMC 100kW Unit, 1 GMC 100kW Unit Top Camp, 1 ESECO 30kW Unit WE Stn., 1 EMU 15E 30kW Unit WE Stn.	Primary - 4 250kW Cummins Units** with Heat Recovery Emergency - 1 MB-18 W 30kW Unit			
HEAT	1 - Birchfield Model R1-3350 FT Firebox-765 #/Hr., Steam 15 - Hot Air Furnaces Furnaces	3 - Cleaver-Brooks Firetube Package Units 150HP Each* 5 - Exhaust Heat Recovery Units on Chicago Pheumatic 350kW Units 4 - HRT Air Furnaces	3 - Kewanee, Firetube Portable FB, 87 HP each 2 - Hot Air Furnaces	3 - Kewanee, Firetube Portable FB 130 HP each 3 - Hot Air Furnaces	2 - Ajax Boilers 2,250,000 Input 1,800,000 Output 4 - 24kW Hot Water Emersion Coils			
FACILITIES	Permanent 49 Semi-Permanent 2 Temporary 5	Permanent 49 Semi-Permanent 10 Temporary 2	Permanent 45 Semi-Permanent 19 Temporary 3		2 Perm.	2 Perm.	2 Perm.	1 Perm.
HOUSING CAPACITY	109	83	134	88	18	20	18	18
RESUPPLY METHODS	Water - Barge Air - Air Force, Charter, Wein Airlines	Water - Barge Air - Air Force, Charter, Wein Airlines	Water - Barge Air - Air Force, Charter, Wein Airlines	Water - Barge Air - Air Force, Charter Wein Airlines	Water - Barge Air - Air Force, Charter Wein Airlines			

*Cape Lisburne boilers retained for MAR

**Cape Newenham has 250kW Caterpillar engines

ENGINE DATA

Make: Cummins

Model: KTA-1150-GC2 (1200 RPM)

			Fuel		
Load	Kilowatts	HP	#/Hr.	G/Hr.	kWh/G.
100%	250	357	116.4	16.4	15.24
75%	188	271	93.72	13.2	14.24
50%	125	182	63.9	9.0	13.88
25%	63	93	33.37	4.7	13.40

PHYSICAL CHARACTERISTICS OF DIESEL FUELS

	Weight Fuel		Heat Value		Sp Gravity at 60°F. 15.5°C	Gravity
	LB/Gal	kg/l	BTU/Gal	kJ/l		Deg. API
#1	6.79	.814	133,900	37,545	.816	42
#2	7.29	.874	138,700	39,524	.876	30

Ratings: Based on #2 Diesel Fuel
Derate 3% for #1 Diesel Fuel

Calculated Electrical Efficiency (HHV):

Load	Efficiency
100%	37.5
75%	35.0
50%	34.2
25%	33.0

Electric Generator Power Factor at Full Load: .80

Figure 5. Engine Data for Phase IIA. Sites

The engine/generator-sets are on isolated concrete pads 15'L x 5'5"W. The sets are on steel frames that measure 13'8"L x 3'2"W.

2.2.2 General System Description

The engine operating sequence for Phase IIA sites is also similar to the Phase I operating sequence with two units operating with 20 percent reserve capacity, and one unit on stand-by and the fourth unit down for maintenance. The MAR facility electrical peak calculated by the Corps of Engineers for Ft. Yukon which is representative of the other Phase IIA facilities is estimated at 444 kW.

Detailed data obtained from the Cape Newenham (Phase IIA) MAR site in early spring yields an actual operating scenario as follows:

> Peak demand of 300 kW required two generators on-line;
> Minimum demand of 230 kW required one generator on-line.

During the peak demand period one boiler was activated. During the peak period two generators were operating at 60 percent capacity and during the minimum period one generator was operating at 92 percent capacity. The average demand for the month was 262 kW.

2.3 PHASE IIB MAR FACILITIES

The second group of Phase II MAR sites consists of the construction of new support facilities that fit the basic concept of MAR installation. These facilities, however, are not isolated and will not be designed with the total energy system concept of the Phase I and the Phase IIA facilities. The second group of four sites, Galena, Kotzebue, Cold Bay and Murphy Dome, will purchase power from local utilities or adjacent Air Force bases and will have emergency generators. The following is a brief description of each site:

- Kotzebue will purchase power from the Kotzebue Electric Association and will have one 275 kW standby generator. System voltages are 120/208 volts, 3Ø,4W. Because of the likelihood of frequent utility outages at this site (for as much as a month at a time according to the Alaskan Air Command's contractor, RCA), a small portable generator will also be provided to feed the building heating equipment and minimal lighting loads. The facility will be manned by three permanent and two part-time personnel.

- Murphy Dome renovations consist of interior construction of living and sleeping quarters for two people, provision for emergency power generation (150 kW) and electrical tie-in to the Golden Valley Electric Association.

- The MAR facility at Galena Airport (AFB) will be connected to the base electrical grid. The emergency power requirement is approximately 160 kW and the electrical service is 120/208 volts.

- The original design for Cold Bay has been changed from two 250 kW 1200 RPM, diesels connected to the Cold Bay base electrical grid to emergency generator status only. The total connected emergency load is approximately 300 KVA at 0.8 power factor, which translates to a 240 kW emergency requirement. Final design criteria for this MAR site have not yet been completed.

2.4 DIESEL ENGINE GENERATOR AND HEAT RECOVERY SYSTEM DESCRIPTIONS

Appendix B contains the power plant description for a typical Phase IIA MAR facility with four 250 kW Cummins Diesel Engine Generator Sets providing prime power with heat recovery. These types of facility energy systems have been highlighted because the design concept of the Phase I MAR facilities will no longer be employed for new construction by the Alaska District, Army Corps of Engineers. As described in Section 2.2, each engine unit is equipped with jacket water heat recovery and exhaust gas waste heat recovery silencers and has a separate exhaust header system allowing for individual operation. The heating system utilizes a 60/40 solution of glycol-water as a heating medium and the facility is heated with by-product heat recovered from the generating units by means of shell and tube heat exchangers.

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3. REMOTE SITE ENERGY USE PATTERNS

The objective of this task was to obtain, analyze, and summarize thermal and electrical energy usage data for the remote sites. As previously discussed, the remote sites have been in a transition from the LRRS preconversion facilities to the MAR facilities. As a consequence, the format of energy data obtained from the LRRS is considerably different than from the MAR sites. In general, the LRRS data provided more detail than the MAR sites data.

The data for the LRPS facilities consists of gross monthly oil consumption and corresponding degree-day data. Yearly totals for kilowatt-hour (kWh) usage and BTUs consumed were also obtained. Data from the MAR facilities consists of gross monthly oil consumption, corresponding degree-days, and total kWh generated on a monthly basis. The data from the MAR sites does not include heat consumption. Procedures were established with the Alaskan Air Command and representatives from RCA for SAIC to continue receiving this information on a monthly basis for inclusion into the data file for continual analysis.

In this section, data from the LRRS and MAR facilities is presented separately. The LRRS data is presented for 1984 and the MAR sites data for 1985. The data from the MAR sites is more extensively evaluated because it is more relevant to the goals of the project.

3.1 PRECONVERSION (LRRS) SITE DATA - 1984

Historical data of preconversion facilities consisted of two standard forms used by RCA and Air Force personnel at Elemendorf Air Force Base. The monthly form, CDRL A079, consisted of gross diesel fuel oil consumption by the facility and the corresponding degree-days for that month. A sample of one of these forms is shown in Table 5. A breakdown of fuel usage by function was not reported. The second form was the CDRL A039. Specifically, two types of A039s were submitted; an Electrical Service Form (Table 6) and the Heat Service Form (Table 7).

Table 5. Fuel Usage A079 Form

CDRL A079
SEPTEMBER 1984

STATION	BARRELS OF FUEL	DEGREE DAYS	SQ. FT. CHANGES	FACILITY	SEPARATE METER FUEL
INDIAN MOUNTAIN	1,087	713.0	0		N/A
FORT YUKON	487	397.5	0		N/A
TIN CITY	696	674.5	0		N/A
CAPE LISBURNE	638	748.0	0		N/A
COLD BAY	429	459.5	0		N/A
TATALINA	871	526.0	0		N/A
SPARREVOHN	805	560.0	0		N/A
CAMPION	99	0.0	FACILITY DEACTIVATED 01 OCT 8		
MURPHY DOME	415	650.5	0		N/A
KOTZEBUE	371	600.0	0		N/A
CAPE NEWENHAM	566	518.0	0		N/A
CAPE ROMANZOF	813	550.0	0		N/A
TOTAL	7,277	6397.0			

Table 6. Electrical Service A039 Form

CDRL A039

ELECTRICAL SERVICE DATE: Yr. Ending 30 Sep 84

INDIAN MOUNTAIN LRRS

Worksheet for computing the Utility Sales Rate for Government-Owned/Operated Facilities per AFR 91-5 and AFM 170-27.

ANNUAL USAGE: 3,706,000 KWH ANNUAL PURCHASED COST: $680,671.00

ORIGINAL COST OF FACILITY FURNISHING SERVICE: $1,511,483.00 7,884 MWH

	CAC	TOTAL COST	ANNUAL CONSUMPTION	UNIT COST
A. BASIC COST (Operations):				
(1) Purchased:	-0-	$ -0-	-0-	$ -0-
(2) Base Produced:	26000	$680,671	3,706,000	$ 0.1837
	53010	$126,093	3,706,000	$ 0.0341
SUB-TOTAL:		$806,764	3,706,000	$ 0.2177
B. LINE LOSSES (estimated)				$ 0.0109
C. SYSTEM COSTS (maintenance)	53015	$ 6,156	3,706,000	$ 0.0017
D. OTHER UTILITY COST:				$ -0-
E. DoD FEDERAL AGENCIES, AND AIR NATIONAL GUARD SALES RATE:				$ 0.2203
F. CAPITAL CHARGES				$ 0.0192
G. ADMINISTRATIVE OVERHEAD				$ 0.0069
H. GROSS SALES RATE (Non-U.S. Govt. Agencies):				$ 0.2464

(0515C)

Table 7. Heat Service A039 Form

CDRL A039

HEAT SERVICE DATE: Yr. Ending 30 Sep 84

INDIAN MOUNTAIN LRRS

Worksheet for computing the Utility Sales Rate for Government-Owned/Operated Facilities per AFR 91-5 and AFM 170-27.

ANNUAL USAGE: 20,887 MBTU ANNUAL PURCHASED COST: $60,606.00

ORIGINAL COST OF FACILITY FURNISHING SERVICE: $390,250.00 126,232 MBTU

	CAC	TOTAL COST	ANNUAL CONSUMPTION	UNIT COST
A. BASIC COST (Operations):				
(1) Purchased: N/A				
(2) Base Produced:	24010	$60,606	20,887	$ 2.9017
	24020	$242,096	20,887	$11.5908
SUB-TOTAL:		$302,702	20,887	$14.4924
B. LINE LOSSES (estimated):				$ 1.0870
C. SYSTEM COSTS (maintenance):	53020	$ 41,822	20,887	$ 2.0023
	53030	$ 9,467	20,887	$ 0.4533
SUB-TOTAL:		$ 51,289	20,887	$ 2.4556
D. OTHER UTILITY COST:				$ -0-
E. DoD FEDERAL AGENCIES, AND AIR NATIONAL GUARD SALES RATE:				$18.0350
F. CAPITAL CHARGES				$ 0.3091
G. ADMINISTRATIVE OVERHEAD				$ 0.5411
H. GROSS SALES RATE (Non-U.S. Govt. Agencies):				$18.8852

(0516C)

Referring to the sample Electrical Service Form (Table 6), annual electrical usage by the facility was recorded and submitted by RCA to the Air Force. Indian Mountain produced electricity (3,706,000 kWh) with its prime power electrical generating plants at a cost of $680,671 or $.1837/kWh. The 26000 CAC account number is the code that defined this portion of the form. CAC 53010 is the cost of maintaining the generating units in $/kWh and CAC 53015 refers to the costs of maintaining the distribution and transmission system of the facility.

Table 7, the Heat Service Form, accounts for the amount of diesel fuel consumed by the facility's boiler system for supplemental heat and associated maintenance costs for operating the system. Referring to the CAC numbers of Table 7, CAC 24010 is the cost of maintenance per million Btu for heating plant operations over 3,500,000 Btuh capacity. CAC 24020 is the cost of #2 diesel fuel oil per MBtu consumed by the facility. The cost of fuel at $11.59/MBtu is equivalent to $1.60/gal of #2 diesel. CAC's 53020 and 53030 are maintenance costs associated with the boiler system heat, steam and water distribution lines.

Table 8 is a summary of the fuel use information obtained from the A039 Electrical and Heat Service Forms for each site. Referring to the electrical and thermal usage column, MWH is the annual Megawatt-Hour production of the primary generators required to power the facility electrically, and MBtu refers to the thermal energy required to fire the auxiliary boilers at each site to provide heat and hot water. From these two figures, the site thermal-to-electric, or T/E ratio, has been calculated. The standard T/E ratio is normally calculated by dividing the site thermal load by the electric load and converting to a unitless value. However, at the LRRS, thermal loads are not known and therefore fuel usage is substituted. This results in a good approximation of the T/E ratio. The importance of the T/E ratio lies in matching the facility's energy requirements with the thermal and electric output characteristics of a power plant. Electric and thermal capacity factors of the facilities have been calculated as the ratio of energy delivered to nameplate capacity of primary equipment. This is an important parameter in determining energy system sizing and operating criteria. Table 9 is derived

Table 8. Energy Usage Characteristics at LRRS Facilities - 1984 Data

Site	Electric and Thermal Usage		Electric and Thermal Capacity Factors		Thermal to Electric Ratio
	MWH	MBTU	% Electric	% Thermal	T/E
1) Indian Mountain	3,706	20,887	47.0	16.5	1.65
2) Fort Yukon	2,845	**	18.0	—	—
3) Tin City	2,731	23,730	31.2	20.7	2.54
4) Cape Lisburne	3,215	21,092	26.2	16.0	1.92
5) Cold Bay	3,233	**	30.8	—	—
6) Tatalina	3,050	19,436	34.8	52.7	1.87
7) Sparrevohn	3,860	10,583	24.5	13.6	.80
8) Murphy Dome	*	32,119	—	28.5	—
9) Kotzebue	2,573	**	32.6	—	—
10) Cape Newenham#	2,831	22,294	43.0	29.1	2.31
11) Cape Romanzof	3,055	23,210	34.9	24.2	2.22

* Purchased Power is wheeled through local Air Force Base

** Heat recovery equipment used exclusively at these sites

Data for Cape Newenham is MAR Site Data from 2/84-12/84

Table 9. Fuel Utilization - LRRS 1984 Data

SITE	ENERGY DELIVERED (MBTU)	TOTAL FUEL CONSUMED (MBTU)	FUEL UTILIZATION EFFICIENCY %
Indian Mountain	33,531	87,025	38.5
Fort Yukon	9,707	46,282	20.9 ***
Tin City	33,048	65,576	50.4
Cape Lisburne	32,061	63,607	50.4
Cold Bay	11,056	32,319	34.2 ***
Tatalina	29,842	72,176	41.3
Sparrevohn	23,753	53,966	44.0
Murphy Dome	32,119	42,053	76.3 *
Kotzebue	8,799	44,803	19.63 ***
Cape Newenham **	31,953	53,989	59.2
Cape Romonzof	33,633	68,931	48.8

* Murphy Dome has no onsite electric generation, therefore the fuel utilization efficiency is the heat conversion efficiency only

** Data presented for Cape Newenham is MAR site data from 2/84-12/864

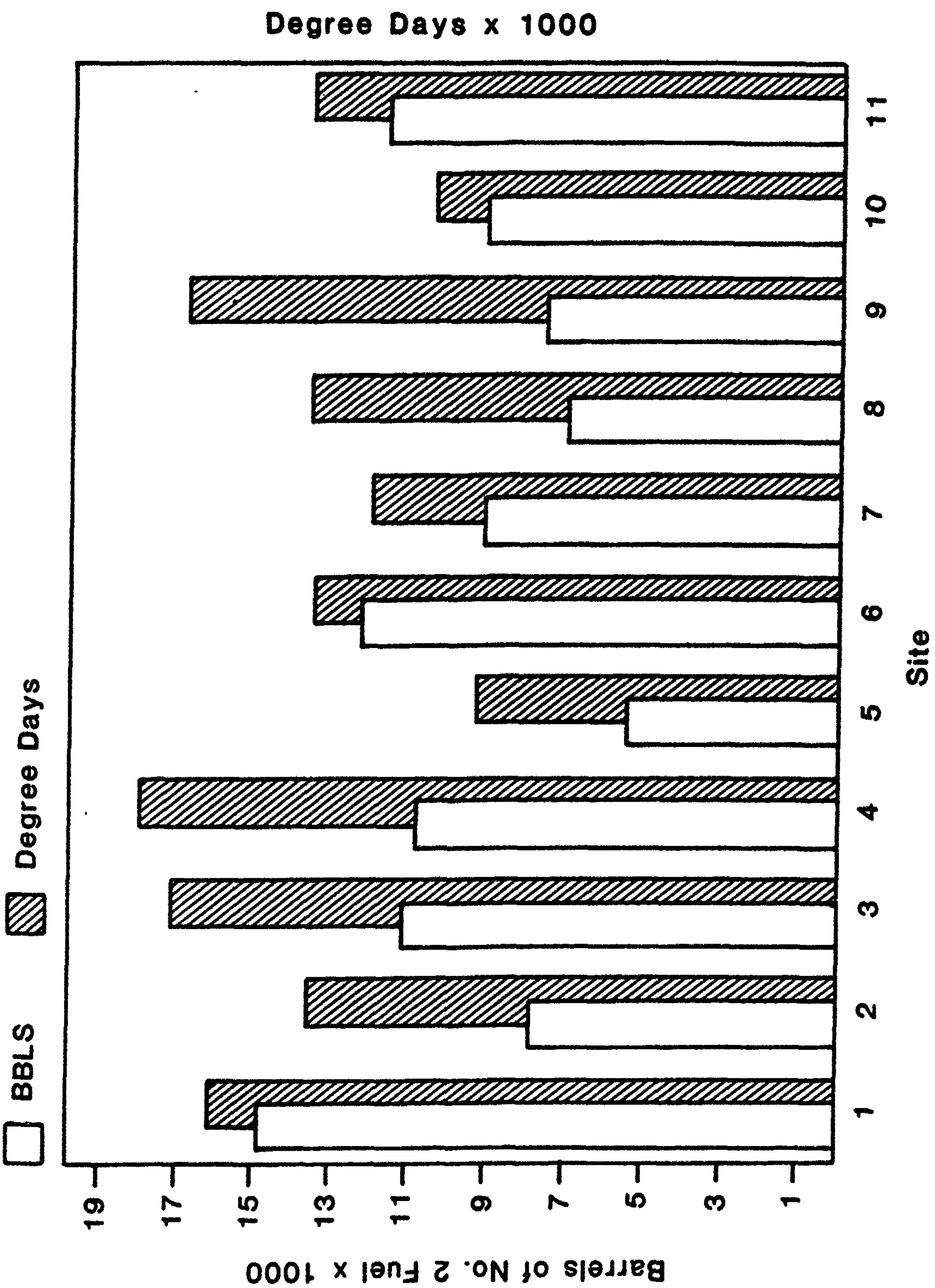
*** Fort Yukon, Cold Bay and Kotzebue were cogenerating heat which is not recorded, therefore, the fuel utilization efficiency does not include cogenerated heat.

from the A079 and A039 forms and compares the fuel utilization of each site. This factor relates to a site's ability to use electricity and by-product heat and is another factor in system sizing. It should be noted that fuel utilization, as used in the case of the LRRS, is not directly comparable to the fuel utilization of a cogeneration system. A cogeneration system should have a much better overall efficiency and therefore a higher fuel utilization than the separate electrical and heating systems of the LRRS. This is because the cogeneration system reclaims and uses otherwise wasted heat from the generators.

Additional comparisons of data parameters have been made from the available information. Appendix C features plots of #2 fuel oil consumption on a monthly basis and the corresponding number of degree-days for each site. As shown in the plots, a correlation exists as expected between the number of degree-days and barrels of oil consumed at a given site. Figure 6 is a summary of each site's total annual fuel consumption and total annual degree-days. The site designation numbers 1-11 correspond to Plots 1-11 in Appendix C, Indian Mountain through Cape Romanzof. The sites are listed in order in Table 8. When the data from all of the sites is analyzed collectively, there is no apparent relationship between fuel consumption and degree-days. As an example, site 9 has more degree days than site 6 but consumes significantly less fuel than site 6. This is apparently due to the variability in the design and architecture of the facilities and the different personnel requirements at each facility at any given time.

3.2 1985 MAR SITE DATA DESCRIPTION

This section addresses energy data from the remote sites for the 1985 calendar year. Most of the data is from MAR sites. In a few cases, data from the preconverted LRRS facilities has been included. Based on discussions with RCA employees and the Alaskan Air Command, the dates for conversion of the sites from LRRS to MAR were s obtained. Upon reviewing the data, it became apparent that there was a significant transitional period between the designated conversion date and the date at which the MAR facility was in full operation. Table 2, previously discussed, lists the dates for LRRS facility



Note: Site numbers correspond to sites listed in Table 8.

Figure 6. Total Fuel Consumption LRRS 1984 Data

termination, MAR facility conversion completion and the transitional period between the two for the Phase I and the Phase IIA sites. During the transitional period the MAR facility was being checked out at the same time the old LRRS facility was still being used. When reviewing the data which follows, it is necessary to differentiate between a MAR facility or a LRRS. Table 2 indicates which type of facility existed in 1985. All of the Phase 1 sites had been converted to MAR sites by summer 1985, while two of the Phase IIA sites are not scheduled to be converted until summer 1986.

Energy data was obtained for the Phase I and Phase IIA sites from the CDRL III-A-2 and the CDRL III-B-2 forms which are commonly referred to as the Boiler Reports and the Diesel Engine Reports. The reports are prepared by RCA employees at MAR sites and are sent to SAIC by RCA or the Alaskan Air Command. Samples of these reports are shown in Figures 7 and 8.

3.3 1985 MAR SITE DATA SUMMARY

The data from the reports discussed in Section 3.2 was entered into a computer data base in a spreadsheet format. The spreadsheets contain monthly information in five categories. These categories are fuel consumption, electricity production, operation parameters, costs and degree days. A sample spreadsheet for the Sparrevohn MAR site is included as Table 10. All of the 1985 spreadsheets are included in Appendix D. A glossary of terms and calculations are also included in Appendix D. Fuel consumption for boiler usages and degree day data was obtained from the Boiler Reports. The remainder of the data was obtained from the Diesel Engine Reports. Monthly averages and annual statistics are also included in the spreadsheets.

All missing data are discussed in the footnotes of each spreadsheet. A blank space represents no available data, while a "0" represents the quantity zero.

Engine, boiler and combined fuel consumption were obtained from the data reports and entered into the computer data base. The fuel consumption data received for boiler usage at Cape Romanzof, Ft. Yukon, and for January

DTG: 021530 JAN 86 *

CDRL: 111-A-2

ENERGY MANAGEMENT REPORT

LRR SITE: SVW

MONTH/YEAR: DEC 85

DIESEL FUEL CONSUMED: 11531

DEGREE DAYS: 1097

SQUARE FOOT CHANGES: NONE

FACILITY: MAR 1

SEPARATE METER FUEL: N/A

COST CODE	DESCRIPTION	GALS.
23020	SMALL HEAT PLANTS	0
24020	BOILER PLANTS	547
26000	POWER GENERATION	10984
42000	INCINERATION	

END OF REPORT/VAN HORN SENDS

Figure 7. MAR Site Boiler Reports

DTG: 021430 JAN 86 *

CDRL: 111-B-2

DIESEL ELECTRIC GENERATION REPORT

LRR SITE: SVW MONTH/YEAR: DEC 85

POWER PLANT

PRIME MOVER				GENERATOR		
BLDG NO	UNIT NO	UNIT SERIAL NUMBER	MFG	HP	KW	VOLTS
2	1	31128017	CUMMINS	315	175	120/208
2	2	31128019	CUMMINS	315	175	120/208
2	3	31127987	CUMMINS	315	175	120/208
2	4	31123569	CUMMINS	315	175	120/208

PRODUCTION DATA

BY UNITS						PLANT TOTALS		
UNIT NO	TOTAL ENGINE HOURS	HRS RUN	GALS OIL BETWEEN CHANGE	LUBE USED AT CHANGE	SITE MAINT. M/H	KILOWATT HOURS	GALS FUEL	KWH PER GAL FUEL
1	5584	426	____	24	8	____	____	____
2	5534	416	____	24	8	____	____	____
3	5599	380	____	24	8	____	____	____
4	5515	353	____	24	8	146160	10984	13.31
		1575						

COST DATA

SITE MAINT M/H: 32@23.00/HR $736.00 FUEL COST/GAL: $1.29

SITE MAINT MATERIAL COST: $884.96 GALS FUEL USED: 10984

LABOR OPERATING COST: TOTAL FUEL COST: $14,169.36

61 HRS @ 23.00/HR $1403.00 LUBE OIL COST/GAL: $3.99

TOTAL PLANT OPERATING COST: $17,576.36 LUBE OIL USED: 96GALS.

COST PER KWH @ SWITCHBOARD: $0.12 TOTAL LUBE OIL COST: $383.04

MAXIMUM DEMAND (KW) BASE 240 MINIMUM DEMAND (KW) BASE 195 3

AVERAGE DEMAND (KW) BASE 215

REMARKS: NO INDIVIDUAL KW METERS OR FUEL METERS FOR UNITS. 0

TOTAL KILOWATT HOURS, GALLONS OF FUEL AND KWH PER GAL ENTERED

ON LINE ABOVE FOR UNIT NO. 4. 0

TOTAL NUMBER INJECTOR CHANGES: 0

PLANT OPERATOR: ROGER STROLE DATE PREPARED: 02 JAN 86

END OF REPORT/VAN HORN SENDS

Figure 8. MAR Site Diesel Engine Report

Table 10. Alaskan Remote Site Energy Data for 1985

ALASKAN REMOTE SITE ENERGY DATA FOR 1985

SPARREVOHN - PHASE I *

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Monthly Value **	Annual Value **
Site Conversion Status	MAR	MAR	MAR	MAR	MAR	MAR	MAR	MAR	MAR	MAR	MAR	MAR		
Fuel Consumption (Gallons)														
Engine	12822	13640	13313	13485	11925	11215	11260	11685	11810	13015	11092	10984	12187	146246
Boiler	0	1610	4503	0	0	0	0	0	0	125	2079	547	739	8864
Total	12822	15250	17816	13485	11925	11215	11260	11685	11810	13140	13171	11531	12926	155110
Electricity Production														
Generation (kWh)	166320	187920	184080	190800	171360	154800	153600	158640	164160	179040	150348	146160	167269	2007228
Maximum Demand (kW)	280	390	360	350	275	275	240	245	260	325	258	240	291	390
Average Demand (kW)	224	280	247	265	230	215	206	213	228	240	209	215	231	
Minimum Demand (kW)	200	230	215	225	195	180	160	205	210	210	190	195	201	160
Efficiency (kWh/gal)	12.97	13.78	13.83	14.15	14.37	13.80	13.64	13.58	13.90	13.70	13.55	13.31		13.73
Efficiency (%) *	0.32	0.34	0.34	0.35	0.35	0.34	0.34	0.33	0.34	0.34	0.33	0.33		0.34
Heat Rate (Btu/kWh) *	10693	10067	10031	9803	9652	10049	10168	10216	9978	10124	10236	10421		10106
Operation Parameters														
Engine Run Time (Hours)														
Cum 31128017 (175 kW)	37	9	155	452	682	584	601	615	693	383	305	476	429	5142
Cum 31128018 (175 kW)	541	410	467	290	287	268	354	272	251	300	450	416	359	4306
Cum 31127987 (175 kW)	413	556	440	290	265	307	290	338	237	423	323	380	355	4262
Cum 31123569 (175 kW)	515	509	456	257	288	294	291	268	294	394	361	353	357	4280
Engine Hours	1506	1484	1518	1489	1522	1453	1536	1493	1475	1500	1439	1575	1499	17990
Total Engine Hours														
31128017 (175 kW)	461	472	626	1282	1964	2548	3149	3764	4457	4840	5145	5584		
31128018 (175 kW)	[illegible]	2251	2718	3009	3297	3565	3919	4191	4442	4742	5192	5534		
Cum 31127987 (175 kW)	1740	2298	2740	3031	3274	3581	3871	4208	4445	4868	5191	5599		
Cum 31123569 (175 kW)	1790	2289	2748	3007	3297	3591	3882	4150	4444	4838	5199	5515		
Engine kWh Generation **														
Cum 31128017 (175 kW)	4086	1140	18796	83547	76785	62218	40100	65347	77127	45715	31867	39533		566262
Cum 31128018 (175 kW)	59747	51919	56631	37161	32313	28552	35400	28902	27935	35808	47016	38605		479988
Cum 31127987 (175 kW)	45611	70407	53357	37161	29836	32707	29000	35914	26377	50489	33747	35264		479870
Cum 31123569 (175 kW)	56876	64455	55297	32932	32426	31322	29100	28477	32721	47028	37718	32758		481108
Total kWh	166320	187920	184080	190800	171360	154800	153600	158640	164160	179040	150348	146160		2007228
Site Capacity Factor **	0.32	0.40	0.35	0.38	0.33	0.31	0.29	0.30	0.33	0.36	0.30	0.29		[illegible]

Table 10. (Cont.) Alaska Remote Site Energy Data for 1985

Typical Engine Rate	#	0.63	0.72	0.69	0.73	0.64	0.61	0.57	0.61	0.64	0.68	0.60	0.53		0.64
Site Load Factor	##	0.80	0.72	0.69	0.76	0.84	0.78	0.86	0.87	0.88	0.77	0.84	0.85	0.79	0.59
Costs															
Diesel Engine Fuel Cost		16540	17595	17174	17395	15383	14467	14525	15074	15235	16789	14308	14169	15721	188654
Lube Oil Cost		143	143	171	343	335	287	239	239	287	335	239	383	262	3144
Site Maintenance Cost		552	345	414	483	644	552	667	529	552	1196	460	736	594	7130
Site Material Cost		431	431	518	637	766	633	537	530	633	775	686	884	622	7461
Labor Operating Cost		1725	1587	1725	1587	1495	1518	1472	1610	1518	943	1610	1403	1516	18193
Diesel Engine Operating Cost		19391	20101	20002	20445	18623	17457	17440	17982	18225	20038	17303	17575	18715	224582
Additional Heating Cost		0	2077	5809	0	0	0	0	0	0	161	2682	706	953	11435
Total Site Energy Cost		19391	22178	25911	20445	18623	17457	17440	17982	18225	20199	19985	18281	19668	236016
Degree Days		1110	1769	1440	1432	784	427	241	432	704	1426	1364	1097	1019	12226

* The site conversion status is indicated by MAR = sites after conversion, TRANS = sites during LRRS/MAR site transition, and LRRS = sites before transition. The MAR site became fully operational in September 1984.

** Values in these columns are discussed in the text and the glossary for Appendix D.

\+ These values are calculated by assuming a higher heating value of 138700 Btu/gallon of diesel fuel.

++ These values are estimated.

\# This estimate is monthly kWh divided by the engine hours and by 175 kW.

\## The monthly load factor is the kWh divided by the peak demand and by the hours in the month.

and February at Cape Newenham was not consistent with the electric production and was, therefore, not included in the data files.

Values in the "Monthly Average" column are averages for the data deemed reliable. Values in the "Annual Value" column are summations, including data from January 1985 through December 1985. The monthly average and annual columns are calculated in this manner for most of the items in the spreadsheet. The demands, efficiencies, capacity factors, engine rates, and load factors are exceptions and are so noted. The calculations for these factors are included in Appendix D.

Information in the electricity production category includes site kWh generation, site kW demands (maximum, average, minimum), and engine efficiency. The annual value for maximum site kW demand is the largest value among the monthly maximum demands for 1985. This is an important number because it suggests a lower bound for power (kW) generation capacity without backup which will be valuable for future remote site design. Similarly, the value for minimum site kW demand is the smallest value among the monthly minimum demands.

Site electricity production efficiency is calculated in three ways. First, it is listed as electrical energy produced per gallon of diesel fuel (kWh/gal). Then it is converted to a percentage by assuming that the fuel's HHV is 138700 Btu/gallon and using 1 kWh = 3413 Btu. Finally, the heat rate (Btu/kWh) is included. The values entered in the annual value column are calculated in the same manner as the monthly data except annual totals in gallons and kWhs are used.

Information under operation parameters includes monthly run time for each engine, accumulated operation time for each engine, estimated monthly kWh generated by each engine, site capacity factor, typical engine rate, and site load factor. The kWh generation for individual engines is estimated by multiplying the site kWh by the ratio of the run time of the specific engine to the combined engine hours of all the engines at the site. Engines at Cape Newenham were the only ones individually monitored to measure electrical output, so these values are not estimated.

The monthly site capacity factor (SCF) is calculated as follows:

$$\text{SCF} = \frac{\text{site kWh generation per month}}{\text{total rated output at site (kW) x hours per month (h)}}$$

The site capacity factor relates the extent to which equipment is being used. A low capacity factor means that there is a large amount of kW-capacity in reserve which can be used as backup. At a remote site, a low capacity factor is needed to ensure reliable and consistent power. The annual SCF is calculated using annual kWh and hours per year.

The typical engine rate (TER) is defined as:

$$\text{TER} = \frac{\text{site kWh generation}}{\text{SUM (engine rated output (kW) x engine run time (h))}}$$

where SUM signifies a summation of each of the engines at a site. This information can be used to determine whether diesels are running at rates where efficiency is high and maintenance is low. The values of the TER and the SCF in the annual total column are calculated in the same manner as the monthly data except annual totals are used instead of monthly values.

The monthly site load factor (SLF) is:

$$\text{SLF} = \frac{\text{site kWh generation}}{\text{maximum demand (kw) x hours in month (h)}}$$

Sites with relatively constant electrical power demands and little variance between the maximum and minimum demands will have high electrical SLFs. A high SLF is also indicative of how well the operating personnel manage the energy system. The value of SLF in the monthly average column is:

$$\text{SLF (monthly average)} = \frac{\text{monthly average kWh}}{\text{average max demand (kW) x avg days per month x 24 h}}$$

The value of the SLF in the annual value column is:

$$\text{SLF (annual total)} = \frac{\text{site kWh generation per year}}{\text{annual max. demand (kW)} \times \text{days per year} \times 24 \text{ hrs.}}$$

The annual value for the SLF is usually much smaller than the monthly SLFs, but it is more significant. A site with a low annual load factor will require more extensive generator load following and will generally mean lower generator efficiency than a site with a higher SLF.

The costs category includes expenses for diesel engine fuel, lube oil, site maintenance, materials, labor, and additional heating as reported by the remote site personnel. There is a tremendous drop in operating cost following the LRRS-MAR conversion due to the reduction in manpower required at the site. As an example, the total operating cost at Ft. Yukon in March 1985, was $65,577. This value dropped to $10,006 in April 1986 following the conversion from LRRS status to the MAR facility.

The degree days listed at the end of the spreadsheet can be used to estimate space heating needs.

3.4 MAR SITES ENERGY DATA SUMMARY

A statistical summary of data presented in the spreadsheets of Appendix D is shown in Table 11. To normalize the data, entries such as degree days, kWh generation, and the T/E ratio are based on monthly averages. Sites have different personnel, different LRRS to MAR conversion time periods, different climatic effects, and different building types that cause significant variations in energy consumption. Thus, it is important to consider each site individually. However, the summarized data shows trends which are helpful to understand the energy usage patterns of individual sites.

The average monthly degree days were calculated using only degree day data for months in which other energy data was also available. For example, the MAR site energy data for Ft. Yukon was obtained only during the spring and

Table 11. Statistical Summary of 1985 Alaskan Remote Site Energy Data

	Average Monthly Degree Days	T/E Ratio	Site Capacity Factor	Average Monthly kWh Generation	Site Engine Rate	Annual Site Load Factor	Maximum Peak Demand (kW)	Electrical Efficiency
PHASE I								
Indian Mountain (MAR) +	989		.38	195151	.74			.34
Sparrevohn (MAR)	1019		.33	167269	.64	.59	390	.34
Tatalina (MAR) ++	575		.38	196197	.61			.36
Cape Romanzof (MAR)	980		.47	240824	.76	.64	510	.37
PHASE IIA								
Cape Newenham (MAR)	928		.24	178740	.51	.70	350	.29
Fort Yukon (MAR)	721		.12	87498	.45	.50	240	.35
Fort Yukon (LRRS)	1615	1.68	.14	199603	.49	.60	465	.29
Cape Lisburne (LRRS)	1373	1.48	.19	246028	.48	.55	612	.30
Tin City (LRRS) *	1267	.69	.28	222271	.68	.69	443	.28

+ The reported kW demand for Indian Mountian appears erroneous during January through September.

++ Demand data was not reported for Tatalina.

* Data regarding the emergency back-up units is not included in this summary.

summer months. Therefore, the average degree days per month was 721 for the spring and summer months. On the other hand, the LRRS data for Ft. Yukon was taken during winter months and the average degree days per month for this time period was 1615. The degree day data is included so that climatic effects can be considered when analyzing the data. A better comparison of the climatic conditions of the remote sites is obtained from the 1984 LRRS data in Section 3.1.

The T/E ratio shown in Table 11 is only given for LRRS facilities. Sufficient data does not exist at the MAR sites to make this calculation because these sites use cogeneration and the heat production is not recorded. They also use electric heaters which are not separately monitored. Therefore, the T/E ratio calculated using only fuel consumption at the MAR sites would not be a valid representation of the actual thermal and electrical energy needs of the sites.

The site capacity factors for the Phase I sites are fairly consistent. This was expected since they are all of very similar design. They range from .33 to .47, thus leaving the majority of the kW-capacity available for reserve. The Phase IIA sites do not show such consistency. This is partly because the LRRS designs are not generic. The MAR site at Ft. Yukon had a low site capacity factor (.12) because the available data was for the summer months when low demand was required. It is also suspected that the building design has a lower heat loss than originally considered and the personnel provide very efficient plant operation. The site capacity factor at the Cape Newenham MAR site (.24) is also somewhat low when compared to the Phase I MAR sites. Cape Newenham has four 250 kW Caterpillar diesel engines vs. four 250 or 175 kW Cummins engines at the other MAR sites and the kWh generation at Cape Newenham was comparable. Therefore, insufficient data exists to determine this anomaly.

The average kWh generated per month ranges from a high of 246028 kWh at Cape Lisburne to a low of 87498 kWh at Ft. Yukon (MAR) with the next lowest at 167269 kWh from Sparrevohn. Excluding the Ft. Yukon (MAR) electricity production that was previously discussed, the kWh data is relatively consistent.

The engine rate varies from .61 to .76 for the Phase I sites and .45 to .68 for the Phase IIA sites. The engine rates for the MAR sites range from .45 to .76 and .48 to .68 for the LRRS which tends to indicate that the MAR facilities are a little more optimally designed than the LRRS. Diesel generators run more efficiently at higher loads. Therefore, the engines at the MAR sites are being run more efficiently. The engines at the LRRS were being run at lower loads to increase their reliability due to their age.

The maximum peak demand ranged from 612 kW at Cape Lisburne (LRRS) to 240 kW at Ft. Yukon (MAR) with the next lowest from Cape Newenham at 350 kW. Site load factors range from .50 at Ft. Yukon (LRRS) to .70 at Cape Newenham (MAR). Cape Newenham's relatively high load factor could be partly a result of its more moderate coastal climate. The load factor for Ft. Yukon (MAR) was .45. This suggests that the annual load at Ft. Yukon is not constant and may be indicative of the severe weather fluctuations. The site load factors and maximum peak demands for Tatalina and Indian Mountain were not presented. Tatalina did not report kW demands and the reported kW demands from Indian Mountain were erroneous. The calculated load factors for Tatalina and Indian Mountain were therefore invalid and were not included in Table 11.

The average electrical efficiencies of the 175 and 250 kW Cummins engines at MAR sites ranged from .34 to .37. The 250 kW Caterpillar engines at Cape Newenham had an annual efficiency of .29. Sufficient information regarding the Cummins and Caterpillar 250 kW engines and operating environments are not presently known to determine why the Caterpillar engines have lower efficiencies.

The LRRS facilities had electrical efficiencies that ranged from .28 to .30. The lower efficiencies of the engines at the LRRS facilities were expected due to their older design.

Because 1985 was a year of conversion from LRRS status to MAR sites, the data is not consistent and in some cases not available. Attempts were made to correlate the data and provide better explanations of anomalies. Plots of efficiency vs. degree days, kWh vs. degree days, kWh vs. peak demand,

and kWh vs. site load factor were prepared. However, no specific correlations could be developed other than the ones already discussed. The data presented is very valuable in characterizing the energy consumption at the remote sites and evaluating them for potential fuel cell application. However, it should be considered preliminary. Data collection obtained from actual site monitoring which will be accomplished in a follow-on effort should provide more information for site energy usage evaluation.

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4. FT. YUKON MAR FACILITY DATA ACQUISITION SYSTEM INSTALLATION

This project originally envisioned installation of limited instrumentation at two MAR sites to collect sample data to verify the energy site data previously discussed in Section 3 and to fill in gaps of missing data. However, it became apparent that the data available from the remote sites was of insufficient detail to provide adequate characterizations of remote site energy usage. It was also found that insufficient data existed to characterize the operation of the diesel generators at the sites. This data was required as input to the development of the life cycle cost model discussed in Section 5. Therefore, one MAR site and its associated diesel generators was fully instrumented to obtain hourly electric and thermal data.

Ft. Yukon was selected as the preferred location for the installation of a remotely accessed DAS because it is a Phase 2A site (nondome structure) and would therefore be most representative of any future remote site installations. It was also relatively accessible from Fairbanks and represented a severe north Alaskan climate. A subsequent identical DAS will be installed under a follow-on program at the Sparrevohn Phase I MAR site. It is located in a less severe south Alaskan climate and will help in evaluation of any abnormalities discovered at the first site.

The components of the DAS include the sensors, datalogger and modem for data storage and remote telephone access. The following is a complete description of the DAS installed at Ft. Yukon.

4.1 THERMAL SYSTEM INSTRUMENTATION

Thermal instrumentation is installed to monitor the heat contribution to the MAR facility by the engine heat recovery system, the two boilers, and the electric boost heater. The following sensor placements are shown on Figure 9, Thermal System Instrumentation Diagram.

T_1 - Engine Glycol/Water Supply Temperature

T_2 - Engine Glycol/Water Return Temperature

T_3 - Outlet Temperature Electric Boost Heater

T_4 - Boiler Water Return Temperature

T_5 - Boiler Water Supply Temperature

T_6 - Ambient Outdoor Temperature

FM_1 - Engine Glycol/Water Return Flow

FM_2 - Boiler Water Return Flow

The following thermal energy outputs will be determined using these temperature and flow values.

-- Engine thermal output $BTU_1 = (FM_1)(T_2-T_1)\ Cp$

-- Booster heater output $BTU_2 = (FM_1)(T_3-T_2)\ Cp$

-- Boiler output $BTU_3 = (FM_2)(T_5-T_4)\ Cp$

FM_1 and FM_2 are nonintrusive clamp-on ultrasonic flowmeters. Ultrasonic flowmeters were selected because they have demonstrated commercial accuracy and they alleviate large installation labor requirements and potential leaks. The meters were installed on the 6-inch glycol/water return line to the engines and on the 6-inch water return line to the boilers. The flow to the electric booster heater in the closed loop is the same flow as the glycol/water return flow after passing through the engines.

Clamp-on resistance temperature devices (RTD's) were installed to measure the differential temperature across each of the above mentioned thermal systems. An additional ambient RTD was installed to monitor outdoor temperature at the site.

4.2 FACILITY FUEL CONSUMPTION

Total facility diesel fuel consumption will be obtained by submetering the four diesel engines and the two boilers with 1/2-inch flowmeters (see

Figure 9). Existing flowmeters on the boiler supply and return lines, F_{3S} and F_{3R}, were equipped with four pulse-head adapters to provide input to the datalogger. The adapters are specially manufactered for use on these flowmeters. A supply and return flowmeter is required because continuous recirculation of fuel to both the engines and boilers is the normal operation.

Measurement of the fuel consumption of the diesel engines required the installation of 1/2-inch flowmeters in the supply and return lines of each engine, F_{4S} and F_{4R} (refer to Figure 9). In total, 12 diesel fuel flows are monitored, the supply and return flows of two boilers and four engines.

4.3 FACILITY ELECTRICAL CONSUMPTION

Total facility electrical consumption will be monitored by two 3-phase 4-wire watt transducers, one each on feeder busways MDA and MDB as shown in Figure 10. Three 2500/5 amp current transformers, one per phase, were installed on each of the feeder busways to provide the 5 amp secondary input to the watt transducers. The total site electrical consumption will be obtained by adding the two busways monitored.

Each feeder busway was instrumented to ensure that total facility electrical consumption could be monitored at all times in the event either feeder was isolated due to a fault or maintenance. This is also the reason the system was designed to have redundant electrical busways.

4.4 DATA ACQUISITION AND REMOTE ACCESS

Data from each sensor installed is scanned every 10 seconds, and stored in 15 minute increments in internal nonvolatile RAM memory of the datalogger. During this 15 minute period of 10 second scans, a number of mathematical manipulations are performed on the data.

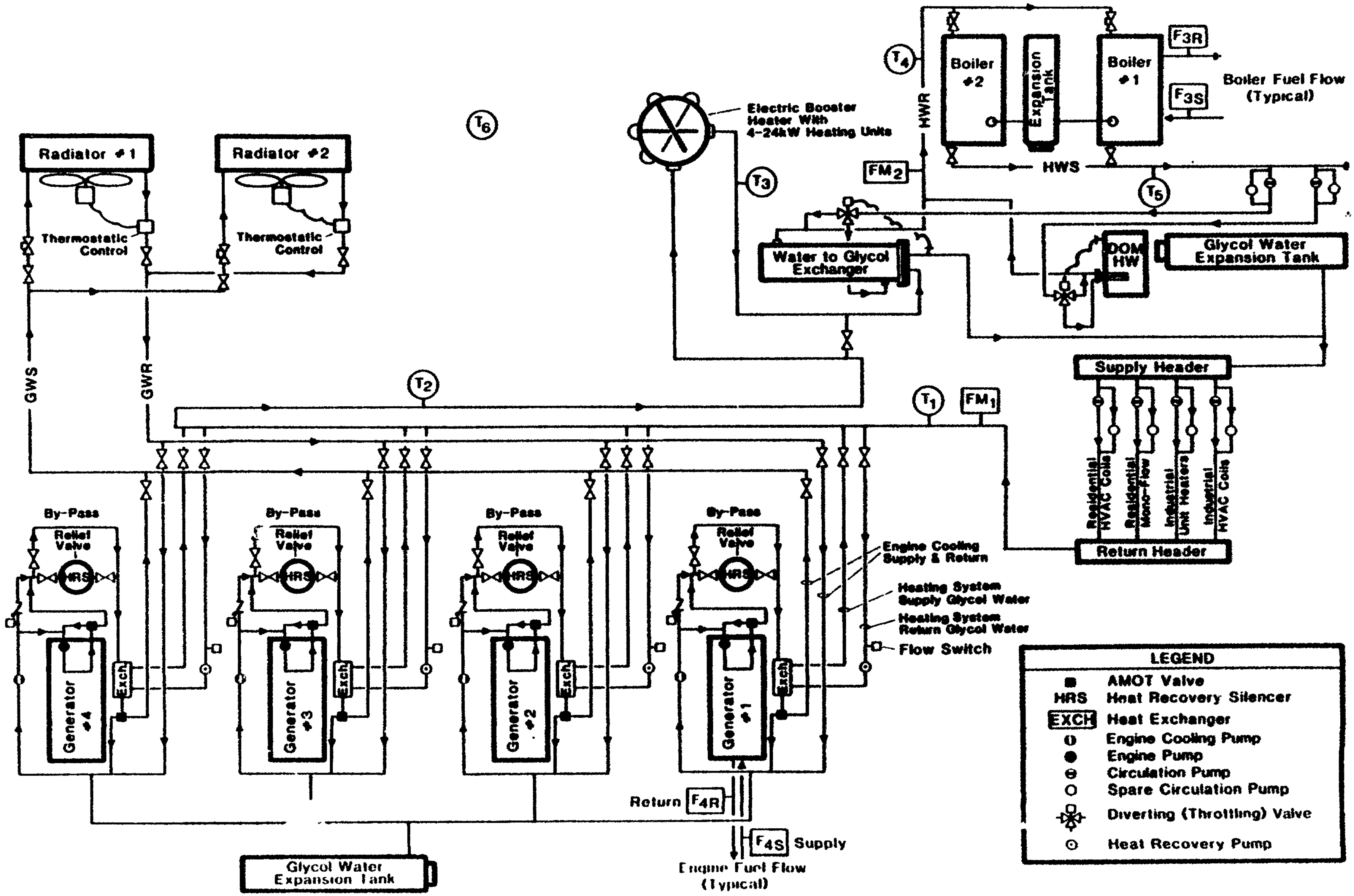

Figure 9. Thermal System Instrumentation Diagram

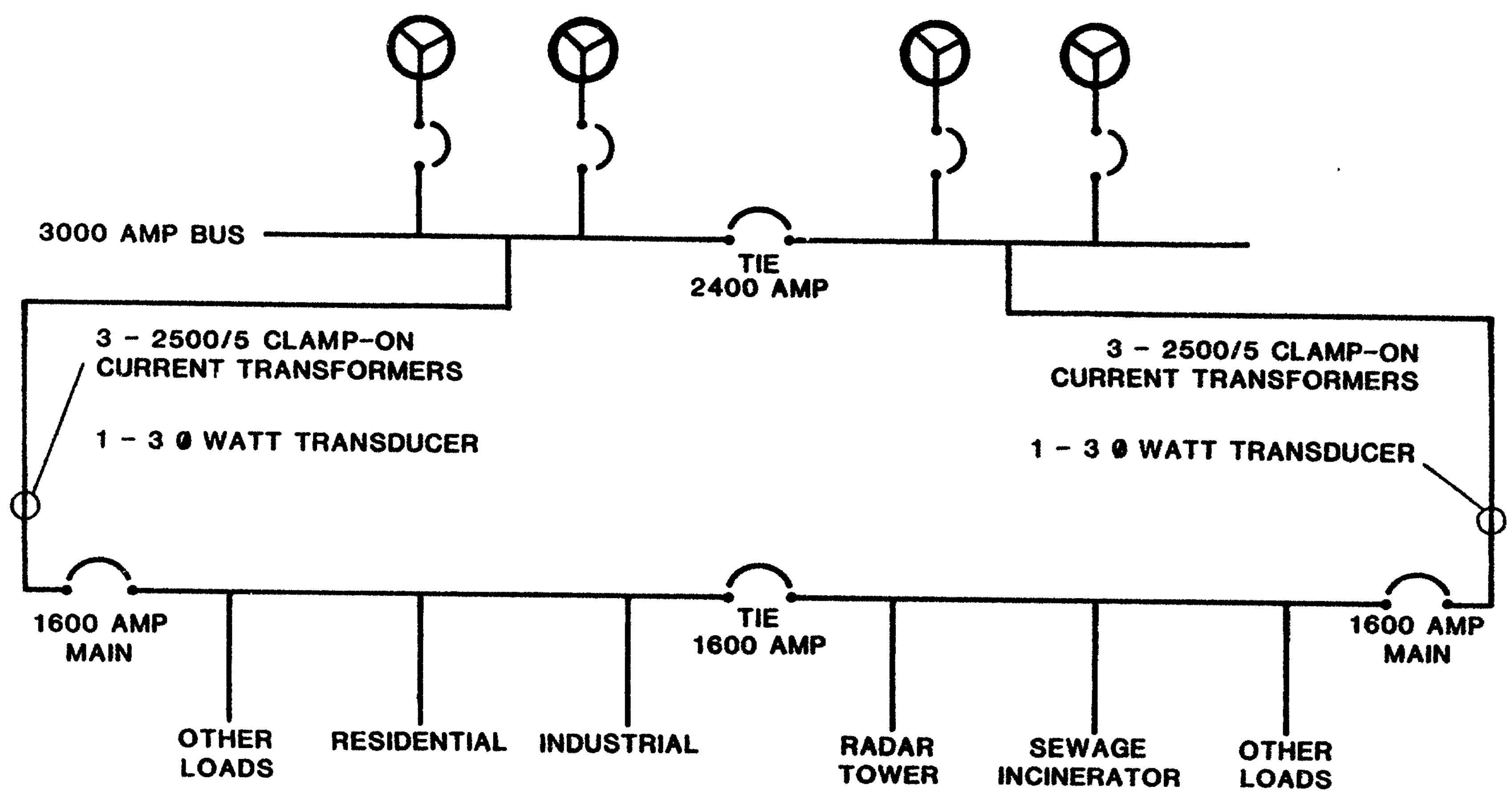

Figure 10. Single Line Diagram - Electrical Instrumentation

These are: MXT...Maximum value of a specified channel for a specified period.

MNT...Minimum value of a specified channel for a specified period.

AVT...Average value of a specified channel for a specified period.

ACC...Accumulated value of a specified channel for a specified period.

Temperatures T_1 through T_6 (°F) are scanned every 10 seconds, and the values obtained are averaged over a 15 minute period (AVT) and then stored in RAM.

Each of the electrical transducers (kW) installed is also scanned every 10 seconds and these values are in turn averaged over the 15 minute period (AVT). The minimum value (MNT) and the maximum value (MXT) are also stored in RAM for the 15 minute period.

The nonintrusive flowmeters FM_1 and FM_2 installed on the glycol/water return and boiler water return lines are scanned every 10 seconds and averaged over a 15 minute data collection period.

The diesel fuel meters are scanned every 10 seconds and the difference between the supply and return meters is calculated to determine system fuel consumption and this value is accumulated over the 15 minute period.

Heat output from the three thermal systems instrumented is performed in a similar manner by performing a thermal load calculation every 10 seconds, accumulating the resulting value over the 15 minute period, and then storing it in RAM. The thermal load calculation ($\dot{m} C_p \Delta T$) is obtained by multiplying the mass flow rate ($\dot{m}$) by the specific heat (Cp) of the fluid and then by the temperature differential (ΔT).

The 15 minute data accumulated in RAM memory is remotely accessed via modem every 24 hours. Figure 11 illustrates the telephone tie between SAIC's

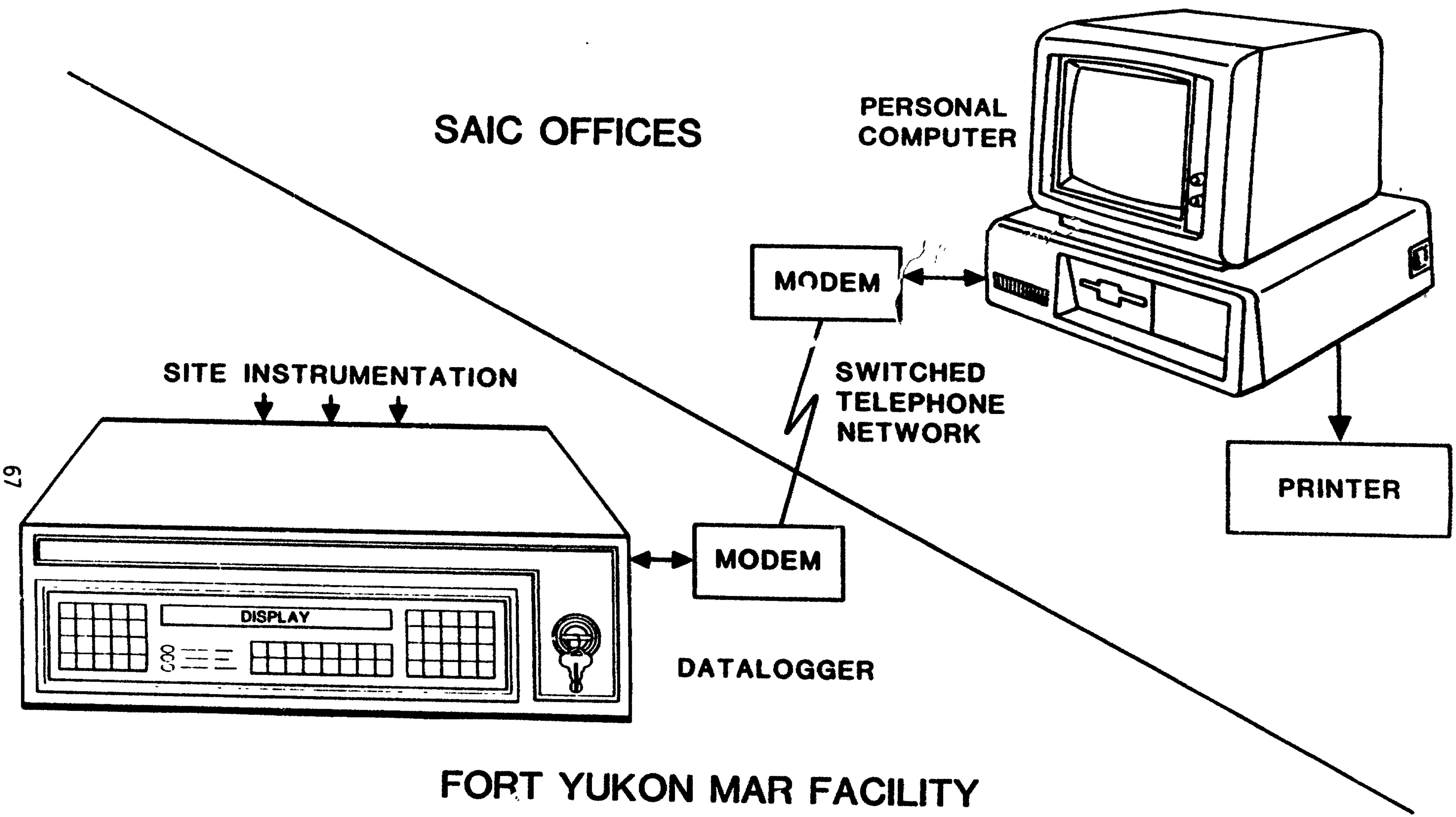

Figure 11. Fort Yukon DAS Schematic

offices in San Diego to the DAS installed at Ft. Yukon. Data is then stored on floppy-disk for further manipulation. The complete datalogger program listing for the data points monitored is shown in Table 12.

The program listing is divided into three primary programming sections. The first programming section, Sensor Inputs is a list of the physical inputs of the parameters monitored, the channel assignments, the engineering unit (EU) assignments which convert analog or pulse inputs into engineering units, and the designated unit label of the converted signal.

The following is a definition of the EU assignments utilized throughout the datalogger program:

EU = 03	0-55mV DC
EU = 05	0-1V DC
EU = 15	RTD, 100-ohm Platinum, $\alpha = 0.00385$
EU = 26	Pseudochannel - allows for data manipulation
EU = 27	Pseudochannel - allows for data manipulation
EU = 47	Digital Input (Pulse)

The second programming section, Cross Channel Calculations, describes the calculated values, assigns a channel where the calculation is performed, lists the corresponding EU value (EU = 26, psuedochannel), defines the mathematical calculation, and designates a unit value.

The third programming section describes 15 minute values stored in the datalogger's nonvolatile RAM memory over a 24 hour period. These values are transferred from the datalogger to SAIC's home computer via the remote data retrieval system. The values include; 15 minute average temperatures, low, average and high values of electrical parameters monitored, accumulated BTU values, glycol-water flows, and diesel fuel consumed.

Table 12. Fort Yukon MAR Site Program Listing

ACUREX AUTOCALC PROGRAM LISTING

SENSOR INPUTS

FORT YUKON FACILITY

ITEM NO.	DESCRIPTION	CHAN	EU	NETPAC LOC. (PORT, MOD, CHAN)	MX+B (1-16)	EXPRESSION	UNITS	LIMITS (00-99)	MESSAGES (00-40)	DEADBAND (00-10)	SCAN (1-2-3-4)
	HEATING SYSTEM GLYCOL/WATER SUPPLY TEMP	000	EU=15				DEGF				
	HEATING SYSTEM GLYCOL/WATER RETURN TEMP	001	EU=15				DEGF				
	OUTLET TEMP ELECTRIC BOOST HEATER	002	EU=15				DEGF				
	INLET TEMP BOILERS	003	EU=15				DEGF				
	OUTLET TEMP BOILERS	004	EU=15				DEGF				
	AMBIENT OUTDOOR TEMP	005	EU=15				DEGF				
	HEATING SYSTEM GLYCOL/WATER FLOW	006	EU=05				GPM				
	BOILER WATER FLOW	007	EU=05				GPM				
	NET ELECTRICAL POWER "A" BUSS	008	EU=03				KW				
	NET ELECTRICAL POWER "B" BUSS	009	EU=03				KW				
	COMBINED "A+B" BUSS KW	010	EU=27			(C8+C9)	KW				
	BOILER #1 FUEL SUPPLY	020	EU=47				GALS				
	BOILER #1 FUEL RETURN	021	EU=47				GALS				
	BOILER #2 FUEL SUPPLY	022	EU=47				GALS				
	BOILER #2 FUEL RETURN	023	EU=47				GALS				
	ENGINE #1 FUEL SUPPLY	024	EU=47				GALS				
	ENGINE #1 FUEL RETURN	025	EU=47				GALS				
	ENGINE #2 FUEL SUPPLY	026	EU=47				GALS				
	ENGINE #2 FUEL RETURN	027	EU=47				GALS				
	ENGINE #3 FUEL SUPPLY	028	EU=47				GALS				
	ENGINE #3 FUEL RETURN	029	EU=47				GALS				
	ENGINE #4 FUEL SUPPLY	030	EU=47				GALS				
	ENGINE #4 FUEL RETURN	031	EU=47				GALS				

Table 12. (Cont.) Fort Yukon MAR Site Program Listing

ACUREX AUTOCALC PROGRAM LISTING

CALCULATED OUTPUTS

FORT YUKON FACILITY

ITEM NO.	DESCRIPTION	CHAN	EU	NETPAC LOC. (PORT, MOD, CHAN)	MX+B (1-16)	EXPRESSION	UNITS	LIMITS (00-99)	MESSAGES (00-40)	DEADBAND (00-10)	SCAN (1-2-3-4)
	HEATING SYSTEM GLYCOL/WATER SUPPLY TEMP AVG	116	27			AVT(C0,1)	DEGF				
	HEATING SYSTEM GLYCOL/WATER RETURN TEMP AVG	117	27			AVT(C1,1)	DEGF				
	ELECTRIC BOOSTER HEATER OUTLET TEMP AVG	118	27			AVT(C2,1)	DEGF				
	INLET TEMP BOILERS AVG	119	27			AVT(C3,1)	DEGF				
	OUTLET TEMP BOILERS AVG	120	27			AVT(C4,1)	DEGF				
	AMBIENT OUTDOOR TEMP AVG	121	27			AVT(C5,1)	DEGF				
	ELECTRICAL POWER "A" BUSS LOW	122	27			MNT(C8,1)	KW				
	ELECTRICAL POWER "A" BUSS HIGH	123	27			MXT(C8,1)	KW				
	ELECTRICAL POWER "A" BUSS AVG	124	27			AVT(C8,1)	KW				
	ELECTRICAL POWER "B" BUSS LOW	125	27			MNT(C9,1)	KW				
	ELECTRICAL POWER "B" BUSS HIGH	126	27			MXT(C9,1)	KW				
	ELECTRICAL POWER "B" BUSS AVG	127	27			AVT(C9,1)	KW				
	ELECTRICAL POWER "A+B" BUSS LOW	128	27			MNT(C10,1)	KW				
	ELECTRICAL POWER "A+B" BUSS HIGH	129	27			MXT(C10,1)	KW				
	ELECTRICAL POWER "A+B" BUSS AVG	130	27			AVT(C10,1)	KW				
	GLYCOL/WATER SYSTEM FLOW ACCUM	134	27			AVT(C6,1)	GPMA				
	BOILER WATER SYSTEM FLOW ACCUM	135	27			AVT(C7,1)	GPMA				
	GLYCOL/WATER SYSTEM BTU ACCUM	136	27			(C101+CN)*C199	BTU				
	BOILER WATER SYSTEM FLOW ACCUM	137	27			(C102+CN)*C199	BTU				
	BOOSTER HEATER SYSTEM BTU ACCUM	138	27			(C103+CN)*C199	BTU				
	FUEL CONSUMPTION GENERATOR #1 ACCUM	139	27			(C104+CN)*C199	GALS				
	FUEL CONSUMPTION GENERATOR #2 ACCUM	140	27			(C105+CN)*C199	GALS				
	FUEL CONSUMPTION GENERATOR #3 ACCUM	141	27			(C106+CN)*C199	GALS				
	FUEL CONSUMPTION GENERATOR #4 ACCUM	142	27			(C107+CN)*C199	GALS				
	FUEL CONSUMPTION BOILER #1 ACCUM	143	27			(C108+CN)*C199	GALS				
	FUEL CONSUMPTION BOILER #2 ACCUM	144	27			(C109+CN)*C199	GALS				

Table 12. (Cont.) Fort Yukon MAR Site Program Listing

ACUREX AUTOCALC PROGRAM LISTING
CRUSS CHANNEL CALCULATIONS

FORT YUKON FACILITY

ITEM NO.	DESCRIPTION	CHAN	EU	NETPAC LOC. (PORT, MOD, CHAN)	MX+B (1-16)	EXPRESSION	UNITS	LIMITS (00-99)	MESSAGES (00-40)	DEADBAND (00-100	SCAN (1-2-3-4)
	GLYCOL SYSTEM BTU CALCULATION	101	EU=26			C6*(7.03/6)*(C0-C1)	BTU				
	BOILER WATER SYSTEM BTU CALCULATION	102	EU=26			C7*(8.09/6)*(C4-C3)	BTU				
	BOOST HEATER SYSTEM BTU CALCULATION	103	EU=26			C6*(7.03/6)*(C2-C0)	BTU				
	FUEL CONSUMPTION GENERATOR #1	104	EU=26			C24-C25	GALS				
	FUEL CONSUMPTION GENERATOR #2	105	EU=26			C26-C27	GALS				
	FUEL CONSUMPTION GENERATOR #3	106	EU=26			C28-C29	GALS				
	FUEL CONSUMPTION GENERATOR #4	107	EU=26			C30-C31	GALS				
	FUEL CONSUMPTION BOILER #1	108	EU=26			C20-C21	GALS				
	FUEL CONSUMPTION BOILER #2	109	EU=26			C22-C23	GALS				

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5. ENERGY SYSTEM LIFE CYCLE COST MODEL

An economic model was developed to evaluate the life cycle cost of remote site energy systems. It was developed specifically to analyze diesel engine systems and fuel cell power plants. However, the model should also be capable of analyzing other energy systems. The model was exercised to prove its validity with actual data from the remote site systems.

5.1 MODEL METHODOLOGY

The life cycle cost model developed is written in FORTRAN and is fully compatible with the IBM Disk Operating System (DOS). The model is menu driven for ease of use. A copy of the menu pages and inputs for a test case are included in Appendix E. The model is programmed for maximum flexibility. In many cases, much more detailed input can be entered than will normally be available.

The life cycle cost model consists of a main program which accesses subroutines. The following is a brief description of all the subroutines. The main program flow chart is shown in Figure 12. A more detailed description of the more complex subroutines is also presented.

1. ZERO : Initializes some of the input variables.
2. INPUT : Reads the input data which has been entered onto the screen and saves it.
3. CINSTAL: Calculates the installation cost of the power plant (see page 77).
4. TOUCAL : This subroutine initiates the system performance calculations by adjusting the input data to be used in the THERMAL subroutine (see page 80).
5. THERMAL: If the fuel consumption as a function of kW or Btu/hr is not given, this subroutine calculates the fuel consumption of the generators and boiler (see page 82).
6. MNTCOST: This subroutine calculates the maintenance cost of the power plant (see page 84).

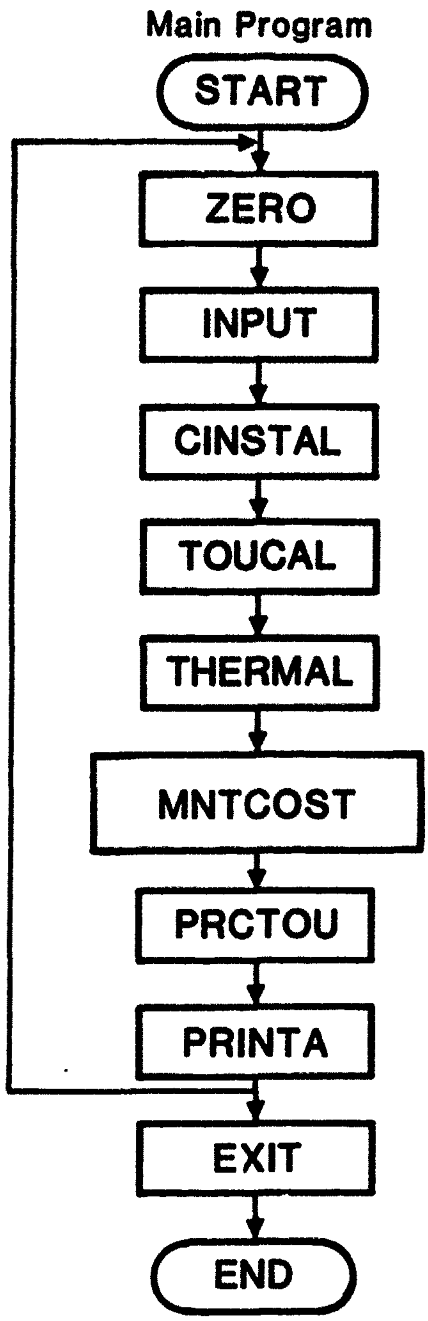


Figure 12. Main Program Flow Chart

7. PRCTOU : Calculates fuel cost for the first year and inflates all costs for the remaining years (see page 86).

8. PRINTA : Prints input and output data.

9. EXIT : Closes the files and ends the program.

Utility Subroutines:

Utility subroutines consist of subroutines that contain parameter lists.

(1) PARAB (XARY, YARY, XIN, YOUT):

This is an interpolating subroutine using Lagrange interpolation.

(2) FRENCH (XARY, YARY, NXIN, YOUT):

This interpolates or extrapolates between three points using the PARAB subroutine.

(3) TRAP2 (IA, IB, I MONTH, RAY, FINT):

This subroutine uses the trapazoidal rule to integrate the given function.

(4) SETUP (RATE, N, RAY):

This subroutine calculates the inflated prices based on the specified inflation rate.

(5) BUILD (ICYEAR, ICMNTH, IUPYR, IUPMNTH, CTIME, ONFAC):

This subroutine calculates construction time based on construction, start date and on line date.

(6) NPV (DOWN, CASH, NYEARS, TZERO, RATE, XNPV):

The NPV subroutine calculates net present value of a cashflow series.

(7) LINE2 (RAY):

Converts an array of 21 real numbers to integer numbers and prints them.

(8) TIME (N, STR):

The TIME subroutine indicates current time.

(9) DATE (N, STR):

The DATE subroutine indicates current date.

(10) CENTER (TITLE):

The CENTER subroutine centers a string of words on an output page.

(11) STRING (IDEVICE, TEXT, IVAR, UNIT):

Rights text to the output device.

(12) STRNG (IDEVICE, TEXT, UNIT):

Same as subroutine STRING with the small change.

INSTALLATION COSTS

Subroutine CINSTAL

Purpose: This subroutine calculates the installation cost of the power plant. Installation cost can be calculated either by the detailed breakdown of the costs or by inputting a lump sum number. In the case of the MAR sites, the installation costs of diesel generator power plants is estimated using historical data. The input data required for calculating the cost consists of the following main categories.

1. Transportation Cost: Transportation cost is calculated predominantly by two variables which are distance and cost per unit distance. Cost per unit distance consists of two variables:

    (1) Cost per unit distance for equipment
    (2) Cost per unit distance for personal

    Transportation Cost Formula:

```
AIRCST(I) = SUM (AIRDIS(I) * AIRRATE(I))
GRNCST(I) = SUM (GRNDIS(I) * GRNRATE(I))
WTRCST(I) = SUM (WTRDIS(I) * WTRRATE(I))
TTCST     = SUM AIRCST + GRNCST+ WTRCST
```

    AIRDIS : Distance by air (miles)
    AIRCST : Air transportation cost ($)
    AIRRATE: Cost by air ($/mile)
    GRNCST : Ground transportation cost ($)
    GRNDIS : Ground distance (miles)
    GRNRATE: Cost by ground ($/mile)
    WTRCST : Water transportation cost ($)
    WTRDIS : Distance by water (miles)
    WTRRATE: Cost by water ($)
    TTCST : Total transportation cost ($)

2. Equipment Cost: Cost of major equipment and other materials to complete the installation is calculated. There are a maximum of 10 major equipment and other material categories provided.

Equipment Cost Formula:

```
EQUPCST = SUM EQIP(I)
PRTCST  = SUM OM(I)         I= 1,...,10

EQIPCST :  Cost of major equipment (array of 10)
EQUIPCST:  Total cost of major equipment
OM      :  Cost of other material (array of 10)
PRTCST  :  Total cost of other materials
```

3. Labor Cost: Labor cost is divided into contracted labor and in-house labor cost. For each case, a different level of labor cost is allowed. Therefore, in-house labor and contracted labor can have different salary levels. The cost will be inflated by the overhead fee factor. Four different salary levels and labor hours for in-house and contracted labor is provided. The formula used to calculate this overall cost is as follows:

```
AILCST = AILHR  * AILRATE
CLCST  = CLHR   * CLRATE
TLCST  = AILCST + CLCST

AILCST  :  In-house labor cost ($)
CLCST   :  Contractor labor cost ($)
TLCST   :  Total labor cost ($)

AILHR   :  In-house labor hour (hr)
AILRATE:   In-house labor rate ($/hr)
CLHR    :  Contractor labor hour (hr)
CLRATE  :  Contractor labor rate ($hr)
```

Figure 13 shows the flow chart for this subroutine.

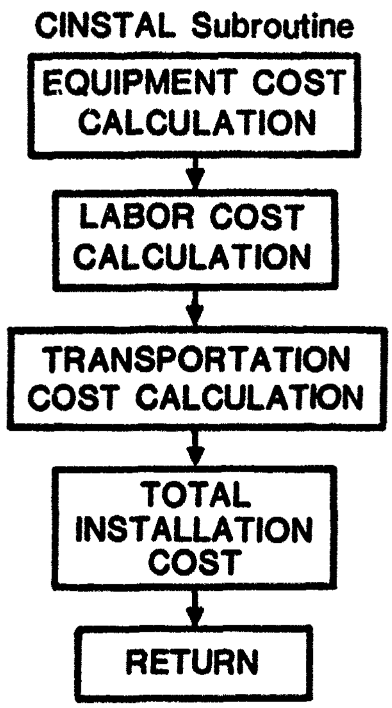


Figure 13. CINSTAL Subroutine Flow Chart

SYSTEM PERFORMANCE

System Performance consists of two subroutines: THERMAL and TOUCAL

Subroutine TOUCAL

Purpose: Subroutine TOUCAL constructs the average hourly load profile per engine. It is assumed that multiple engines are operational at the same time and each one shares an equal portion of the load while an additional generator is on standby. To ensure that the demand does not exceed the capacity of the engines, the program integrates the electrical load profile and the generator's output and compares the two. A flag is set if demand exceeds capacity. To adjust the output to demand, the generator's capacity is compared with the average hourly load profile per month. Then the hours of operation are calculated based on whether the generators are operating. To calculate the net kW hours per day, the integrating subroutine TRAP2 is used.

Input parameters are as follows:

CAPC : Engine capacity (kW)
PRFILE: Average hourly load profile per month

Output parameters are as follows:

POUTG(K,I,J) : Adjusted average hourly load profile per month
ENGY : Net kW demand per month
CAPACM : Net engine output in kW/hrs per month

Figure 14 shows the TOUCAL subroutine flow chart.

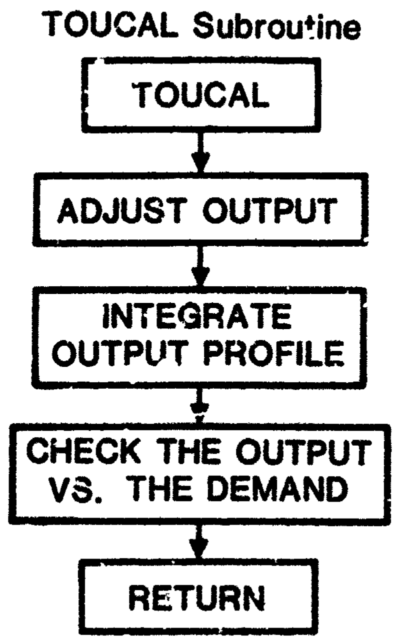


Figure 14. TOUCAL Subroutine Flow Chart

Subroutine THERMAL

Purpose: Subroutine THERMAL calculates the fuel consumption of the generators and boilers.

From site thermal demand data and generator heat output data, the thermal load output of the generators and boilers is calculated. It is assumed that the boiler provides the excess thermal load which cannot be produced by generators; therefore, the adjusted generator and boiler thermal load profile can be obtained.

The interpolating subroutine FRENCH (see page 73) is used to calculate the generator thermal output vs. net electrical output curve. The thermal capacity of the generators is subtracted from demand and the remainder is the boiler thermal load. Then the boiler's operating hours is calculated using the manufacturer's efficiency of the boiler.

The fuel consumption profile is constructed using net kW vs. fuel consumption curve. Then utilizing the integrating subroutine TRAP2 (see page 73) fuel consumption is calculated.

Integrating the thermal loads of the boilers and generators, the total Btus per month that must be produced is obtained. The boiler run time per month is simply calculated using the efficiency of the boiler and its thermal load.

WFG1M(J) = WFG1 [illegible] '(J)/FHH   J=1,...,12

WFG1M(12) = First generator monthly fuel consumption
WFG1 = First generator daily fuel consumption
NDAY(12) = Number of days per month
FHH = Fuel higher heating value

Note: The same calculation is made for additional generators.

WFBLM(J) = THOUTBL(J)/(ETABLE * FHH)

WFBLM(12) = Boiler monthly fuel consumption; gal.
THOUTBL(12) = Boiler thermal output; Btu/hr
ETABL = Boiler efficiency

Figure 15 shows the THERMAL subroutine flow chart.

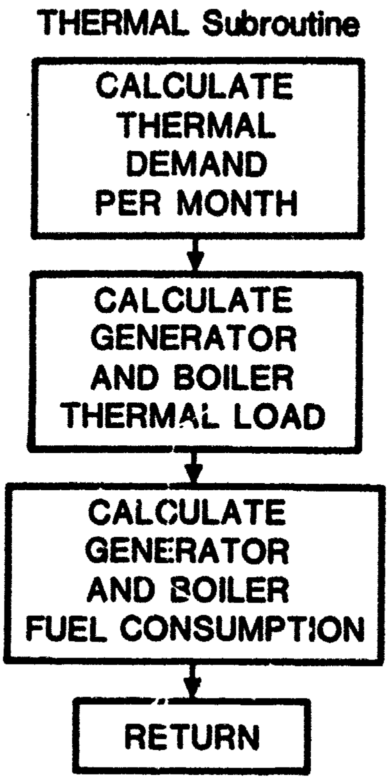


Figure 15. THERMAL Subroutine Flow Chart

Subroutine MNTCOST

Purpose: This subroutine calculates the maintenance cost of the energy system for one year. It is divided into scheduled and unscheduled maintenance costs. The scheduled maintenance cost is calculated using in-house and contracted labor hours, rates and transportation costs.

Two maintenance cycles are incorporated in the program, one for minor maintenance and one for major maintenance. The number of maintenance cycles is based on the engine run times. The program has the option to treat the maintenance cost per year as a lump sum number. The unscheduled maintenance cost is calculated using historical data.

1. Labor Cost:

There are two types of labor considered; in-house and contracted labor and two types of maintenance; scheduled and unscheduled.

```
CMIN  = MIRATE * MILHR
CMC   = MCRATE * MCLHR
UCMIN = MIRATE * UILHR
```

CMIN	:	In-house maintenance labor cost per year ($)
MILHR	:	In-house maintenance labor hours; hr.
MIRATE	:	In-house maintenance labor rate; $/hr
UCMIN	:	Unscheduled in-house maintenance cost; $
UILHR	:	Unscheduled in-house labor

```
CMNT1  = (CMPRT + CMTRNS + CMIN + CMOIL + CMC) * (1 + OVRFEE)
```

CMNT1	:	Total maintenance cost ($)
CMPRT	:	Cost of parts for maintenance ($)
CMOIL	:	Lube oil cost ($)
CMC	:	Cost of contractor maintenance ($)
CMTRNS	:	Transportation cost ($)
OVUFEE	:	Overhead fee (%)

```
UCMNT1 = (UCMTRNS + UCMIN + UCM + CUMPRT) * (1 + UOVRFEE)
```

UCMTRNS	:	Transportation cost for unscheduled maintenance ($)
UCMIN	:	Unscheduled in-house maintenance cost ($)
UCM	:	Unscheduled maintenance cost by contractor ($)
CUMPRT	:	Cost of parts for unscheduled maintenance ($)
UOVRFEE	:	Overhead fee for unscheduled maintenance ($)

Figure 16 shows the MNTCOST subroutine flow chart.

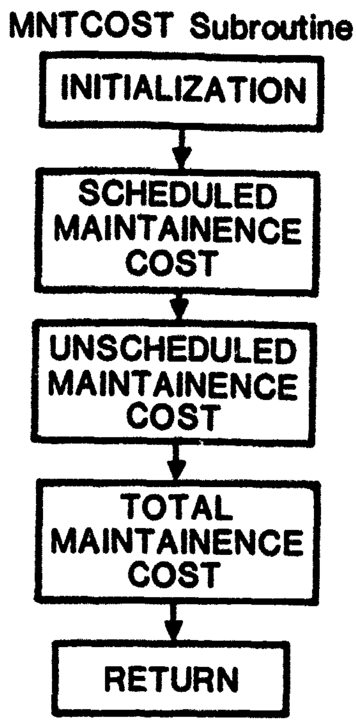


Figure 16. MNTCOST Subroutine Flow Chart

Subroutines PRCTOU

Purpose: The PRCTOU subroutine calculates fuel cost for the base year. Also, maintenance and fuel cost is inflated using subroutine SETUP (see page 73) for all subsequent years. Utilizing subroutine NPV (see page 73), the net present value is calculated. Then the net cost for the duration of the analysis is calculated by summation of annual costs.

Input parameters are:

FULINF : Fuel inflation rate (%)
MNTINF : Maintenance cost inflation rate (%)
FRATE1 : Fuel cost per gallon ($/gal)

Output parameters are:

FULCST : Fuel cost ($)
PLNTCST : Total cost ($)

Figure 17 shows PRCTOU subroutine flow chart.

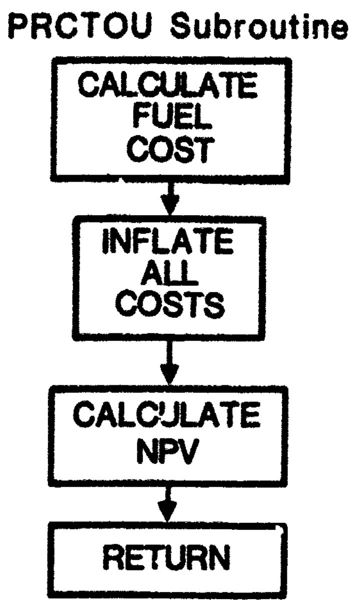


Figure 17. PRCTOU Subroutine Flow Chart

5.2 SAMPLE DATA ANALYSIS

A sample run of the life cycle cost model was made based on the most accurate data available for a generic MAR site. One specific site was not evaluated because a complete set of data inputs was not available from any one site. The data which was available has been used to validate the model and provide the most accurate life cycle cost for a MAR site presently obtainable. Complete input data will be available from instrumented sites under a follow-on program. The calculated life cycle cost for a specific remote site energy system will then be obtainable.

Significant effort was expended to gather the input data. Many individuals from the Alaskan Air Command and the Army Corps of Engineers at the Elmendorf AFB were invaluable in supplying information. Table 13 is a list of the data requested from these individuals.

Table 13. Data Requirements for Life Cycle Cost Program

Parameters		Units
1.0	Prime Mover Data	
1.1	Net Electrical Output	kW
1.2	Net Thermal Output vs. Net Electrical	Btu/hr vs. kW
1.3	Fuel Consumption vs. Net Electrical	Btu/hr vs. kW
1.4	Fuel Higher Heating Value	Btu/gal
2.0	Site Data	
2.1	Electric Load Profile	kW
2.2	Thermal Load Profile	Btu/hr
2.3	Systems Operating Strategy (e.g., two engines operating, two at idle, and two on standby)	
2.4	Standby Boiler Efficiency	%
2.5	Standby Boiler Operating Hours	hrs/yr
2.6	Parasitic Fuel Consumption	gal/hr
3.0	Installation Costs	
3.1	Major Equipment (e.g., engines)	$
3.2	Other Materials	$
3.3	Transportation Distance	miles
3.4	Transportation Costs	$/mile

Table 13. Data Requirements for Life Cycle Cost (Continued)

Parameters	Units
3.0 Installation Costs (continued)	
3.5 Inhouse Labor:	
3.5.1 Labor Hours	hrs
3.5.2 Labor Rate	$/hr
3.6 Contractor Labor:	
3.6.1 Labor Hours	hrs
3.6.2 Labor Rate	$/hr
3.6.3 Overhead & Fee Rate	%
4.0 Operation	
4.1 Fuel	
4.1.1 Basic Fuel Cost	$/gal
4.1.2 Fuel Transportation Costs	$/gal
4.1.3 Fuel Handling Costs	$/gal
4.1.4 Fuel Storage Costs	$/gal
4.2 Maintenance (preventative)	
4.2.1 Schedule	hrs & procedure
4.2.2 Parts Cost	$
4.2.3 Parts Storage Cost	$
4.2.4 Transportation Distance	miles
4.2.5 Transportation Cost	$/mile
4.2.6 Inhouse Labor	
4.2.6.1 Labor Hours	hrs
4.2.6.2 Labor Rate	$/hr
4.2.7 Contractor Labor	
4.2.7.1 Labor Hours	hrs
4.2.7.2 Labor Rate	$/hr
4.2.7.3 Overhead & Fee Rate	%
4.3 Maintenance (unscheduled)	
4.3.1 Mean Time Between Failures	hrs & failure
4.3.2 Parts Cost	$
4.3.3 Parts Storage Cost	$
4.3.4 Transportation Distance	miles
4.3.5 Transportation Cost	$/mile
4.3.6 Inhouse Labor	
4.3.6.1 Labor Hours	hrs
4.3.6.2 Labor Rate	$/hr
4.3.7 Contractor Labor	
4.3.7.1 Labor Hours	hrs
4.3.7.2 Labor Rate	$/hr
4.3.8.2 Overhead & Fee Rate	%

In many cases the data available was not of the form or quality that was needed. Improvisions were made and the resulting inputs are presented in Appendix E.

A total of twelve menu pages for the test case are shown in Appendix E. Initially, the user has the option to edit the input data, read existing input data, run the program or print the model output. Basic system description information is then input. This includes the number of generators, electric and thermal capacities and fuel variables. These inputs for the test case are shown on page E-2. The values used in the test case represent a typical MAR site. The electric capacity was based on a site with four 250 kW diesel generators such as Ft. Yukon. The thermal capacity of the generators was 3200 Btu/HP. A straight line relationship between thermal output and electric output was assumed based on this value because better information was not available from the manufacturer. When more precise data is available from a follow-on program, it can be entered as thermal vs. electrical output as described later in this section. The total boiler capacity and efficiency was supplied by the manufacturer. The fuel higher heating value (HHV) and cost and the lube oil cost was supplied by the Alaskan Air Command. The fuel HHV was given as the same for all MAR sites even though different suppliers are used. Therefore, the accuracy of this number is suspect and will be verified by an actual calorimeter test under a follow-on program. The fuel cost of $1.50 per gallon was the actual cost for fuel at Indian Mountain which was delivered by air transport. The lube oil cost of $4.70 per gallon was an average for all the MAR sites.

The economic factors are then designated. Individual inflation rates for separate costs and prices can be input. Consumer prices will be used to inflate all the costs other than fuel and electricity which have separate inflation rates. The discount rate is used in calculating the net present value. For the test case, 6 percent was used for all the inflation rates.

Installation costs can be input as detailed costs or as a lump sum. The detailed costs can be broken into in-house and contracted labor, transportation cost, and itemized equipment cost. The installation cost for the test case was input as a lump sum of $886,000. The Army Corps of Engineers at the Elmendorf AFB provided a cost breakdown for the Ft. Yukon installation excluding all costs associated with the site electrical system which would have been required for external supplied electricity. The costs do include

the diesel generators, heat recovery equipment and other ancilliary equipment. The data was not of sufficient detail to be input as detailed costs.

Operation and maintenance cost is separated into two categories, scheduled and unscheduled. For each category the inputs are: parts cost, transportation cost, in-house and contracted labor, and overhead/fee. For the test case a lump sum of $48,400 was assumed for the total annual operation and maintenance at a typical MAR site. This value is based on total annual detailed projected maintenance budgets for the Diesel Maintenance Shop at the Elmendorf AFB. The total budget was divided by a weighted average number of remote sites that the Maintenance Shop services to obtain the average maintenance cost for a Phase I or IIA MAR site which was $32,400. The average operating cost from the MAR sites as reported on the CDRL III B-2 forms was $16,000. Unfortunately the data provided could not be broken down into the categories of the model. The value used in the test case includes annual electric overhauls, minor and major diesel engine overhauls, unscheduled maintenance, special projects, bench stock repairs and inventory and all travel associated with the maintenance.

In order to designate the time frame for which the analysis will be run, the construction start date, system on-line date, and number of years to be analyzed, is input. In the test case, the assumption was made that construction was started in January 1986 and completed in one year.

The model requires the monthly lube oil and monthly thermal loads. The test case includes actual lube oil consumption for a typical MAR site.

The total thermal energy requirement per month is necessary to determine heat required from the engines and back-up boilers. Actual data was not available from the MAR sites for the test case. However, fuel consumption data from five MAR sites operating in 1985 along with assumptions of the amount of usable heat produced based on the fuel consumption was used to develop the annual thermal load. Ft. Yukon degree day correlations were used to develop the monthly load profiles. The thermal loads shown on page E-7 are based on these correlations.

The site hourly electric load profile is entered as an average 24-hour day for each month of the year. This data was not available for each month of the year from the MAR sites. Therefore, the test case data listed on pages E-6 and E-7 are based on correlations between very limited LRRS hourly electric demand data and the average total electric production data from the MAR sites.

The thermal energy output and fuel consumption of an engine corresponding to its part load electric output at eight different points is required. As stated earlier in this section, only one point (3200 Btu/HP) was available from the manufacturer for thermal output. Therefore, for the test case, two points are used to represent the straight line relationship. The model interprets between these points to develop the thermal output. The fuel consumption vs. part load electric output was available from the manufacturer and is shown as three sets of values on page E-7.

The results from the calculations performed by the life cycle cost model for the test case are presented as four output pages and tables. Many of the important input parameters describing system performance and cost assumptions also are summarized. Page E-8 of the model output is a relisting of the input variables previously discussed.

The monthly calculated operating data for the test case is presented in tabular form for a complete year as shown on page E-9. This includes engine and boiler fuel consumption, electric and thermal energy production, engine operating hours as a reference and generator and boiler fuel costs.

The year-by-year life cycle cost is presented for the number of years desired. For each year, the fuel cost and maintenance cost are added to provide the net negative cash flow. Using the discount rate supplied, the year-by-year discounted cash flow is presented. The cumulative cash flow and cumulative discounted cash flow are included for each year, leading to the total next present value (NPV) or life cycle cost. For the test case, the NPV was $8,183,727 as shown on page E-11.

Appendix A

Phase I. & Phase II. Site Drawings

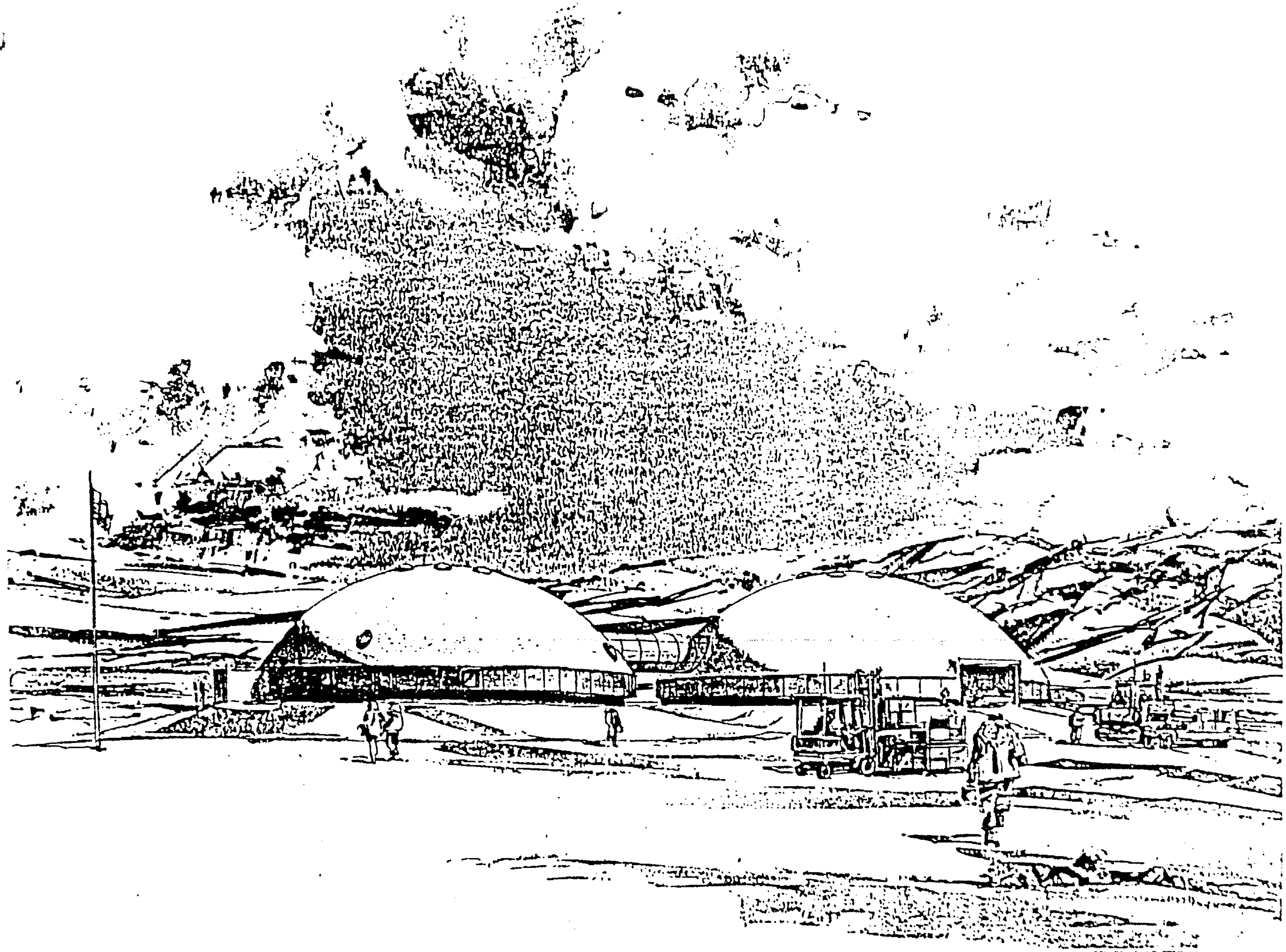
Applicable Codes and Standards for MAR Facilities Design

Mechanical Design

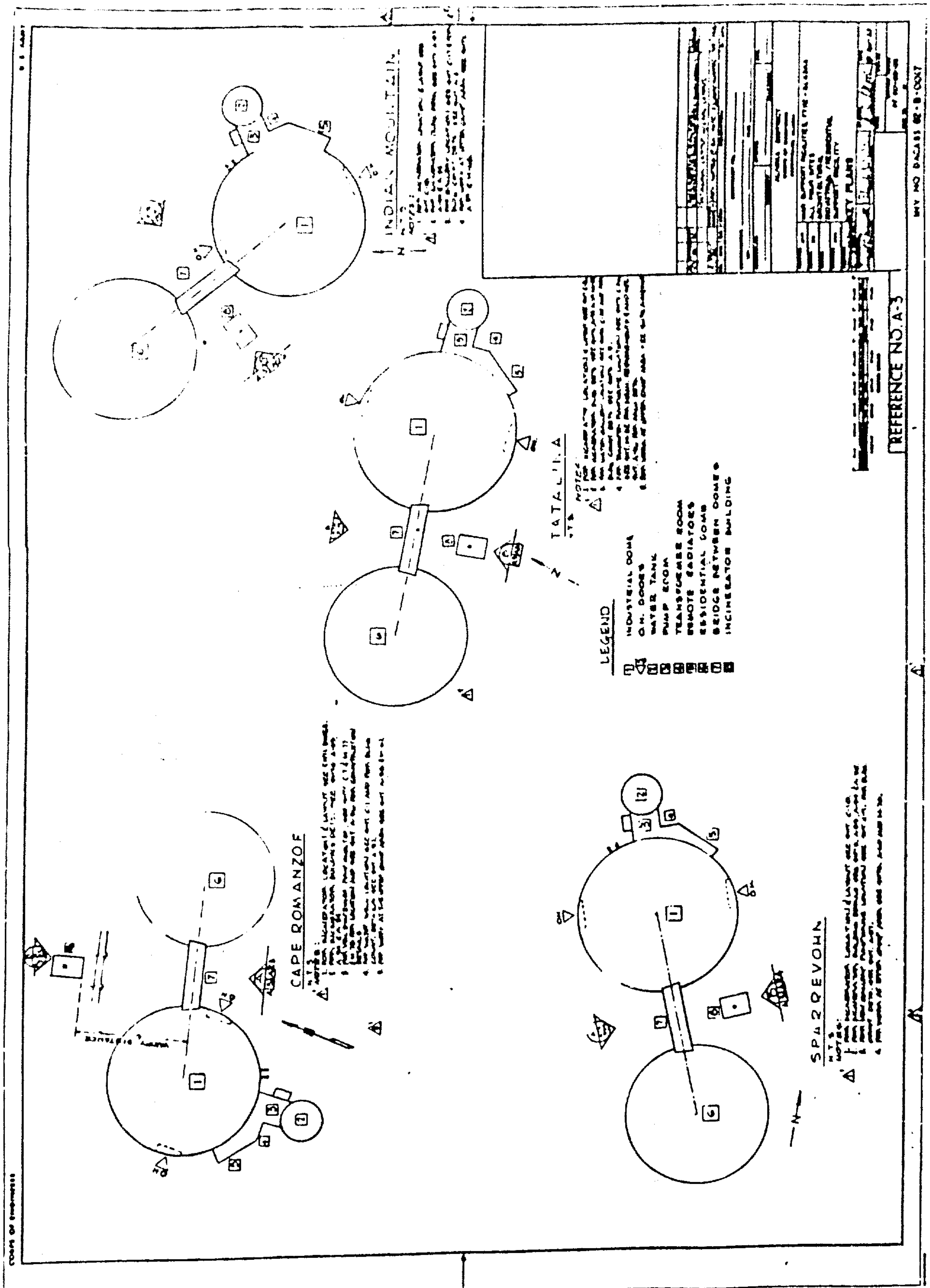
- ASHRAE Guide
- ASME Boiler Code
- ANSI Piping
- NEPA Publications (as applicable)
- Air Force Manual 88-15 (AFM88-15)
- Department of Defense Manual 4270.1 OSHA 1670M
  (DOD 4270-1-M)

Electrical Design

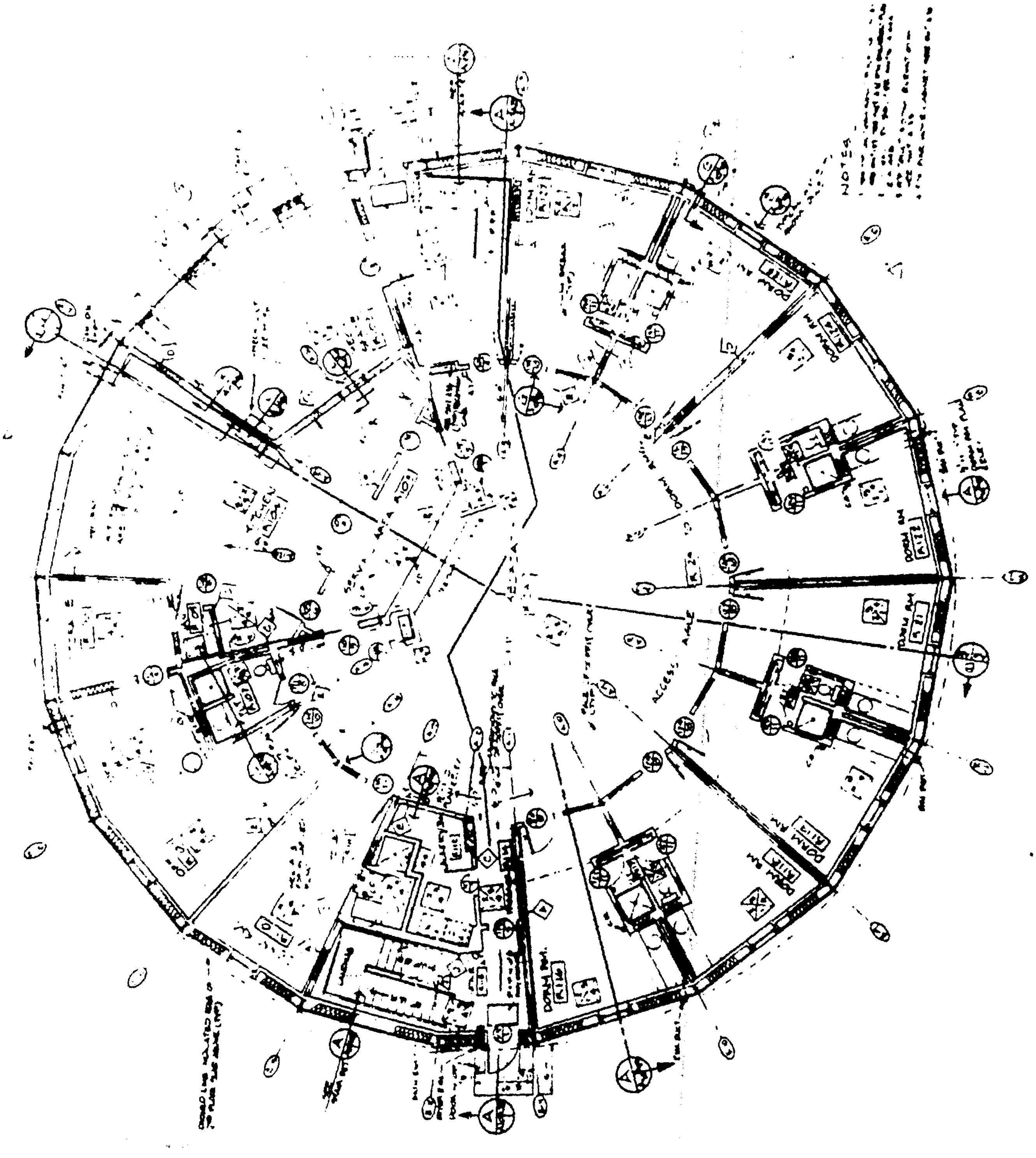
- IES Lighting Handbook
- 1981 National Electrical Code
- 1981 National Electrical Code Handbook
- AFM88-15
- DOD 4270-1-M
- Uniform Building Code
- Air Force Manual 88-8 (Chapter 6)
- ASHRAE Handbook



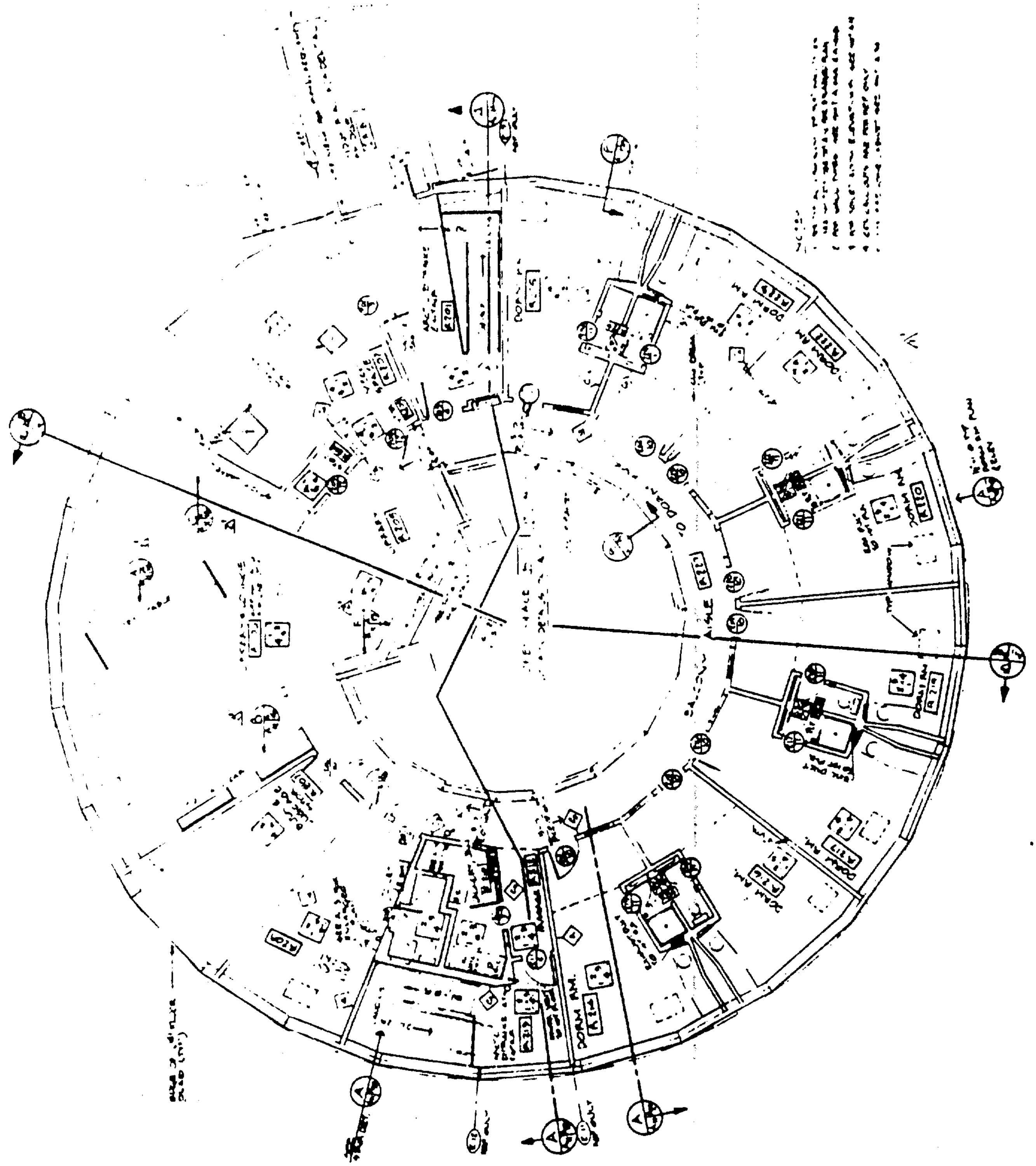
Artists Rendering - Phase I. Geodesic Domes



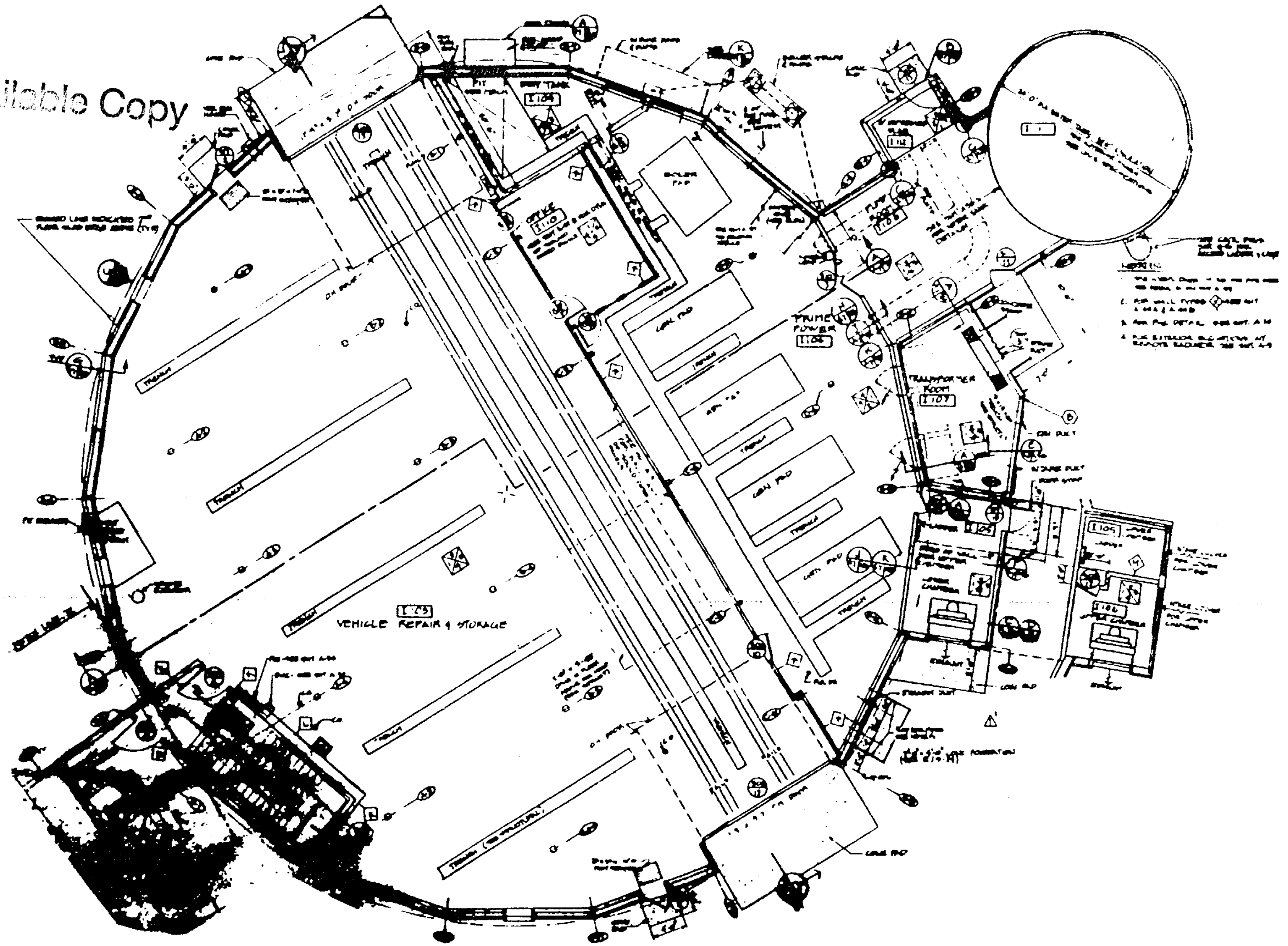
Phase I. MAR Facility's Orientation



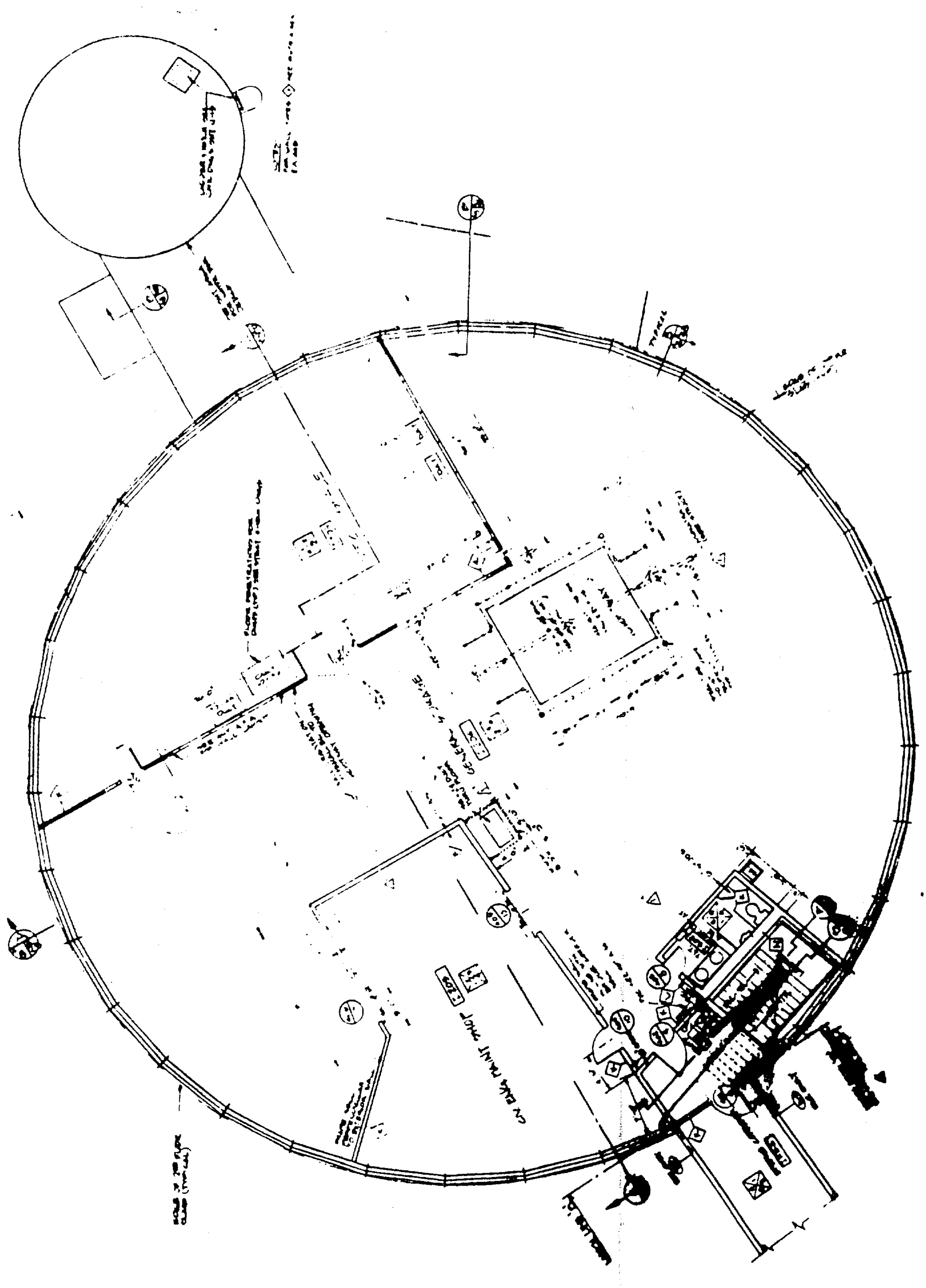
First Floor Residential Dome



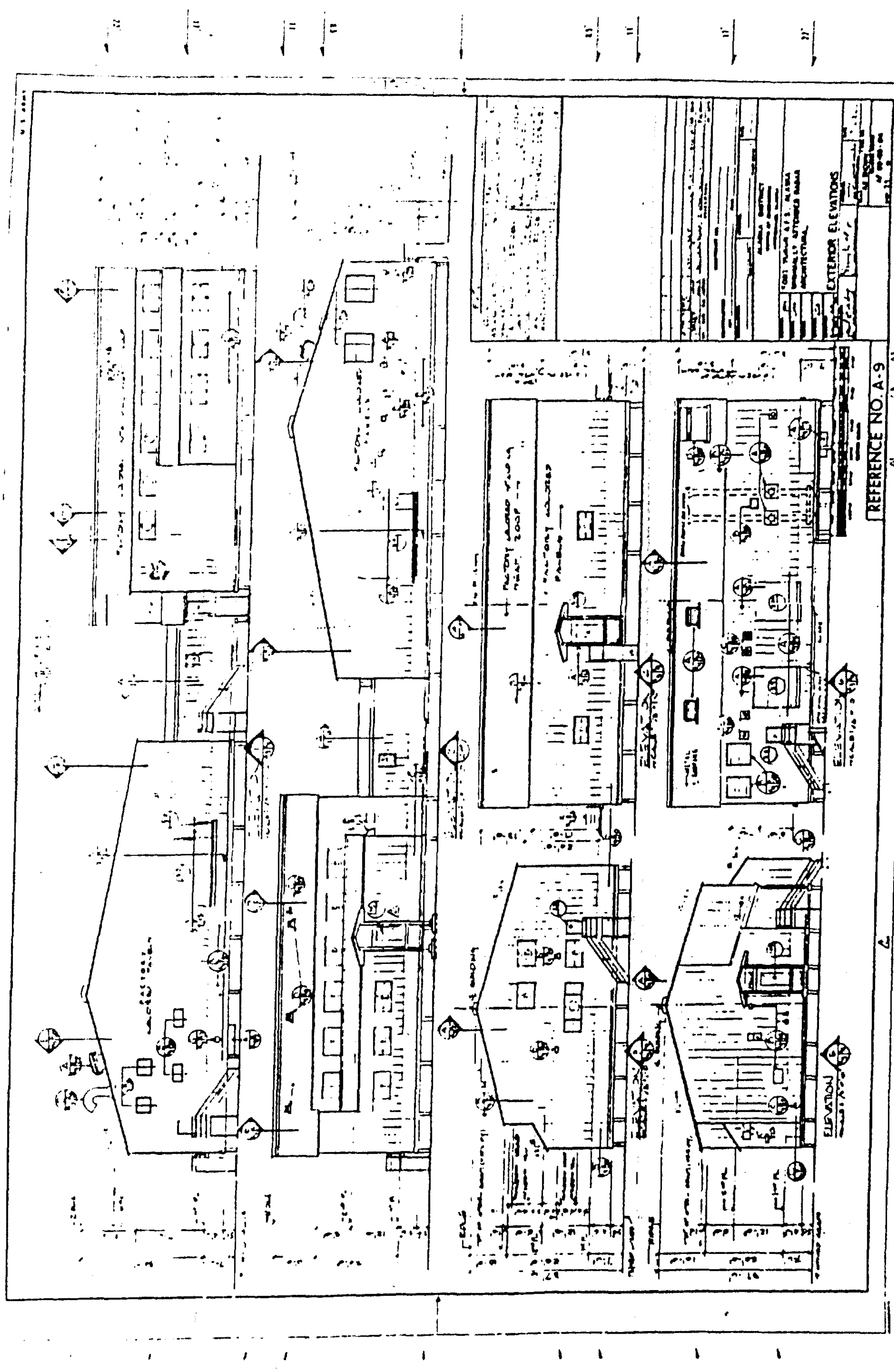
Second Floor Residential Dome



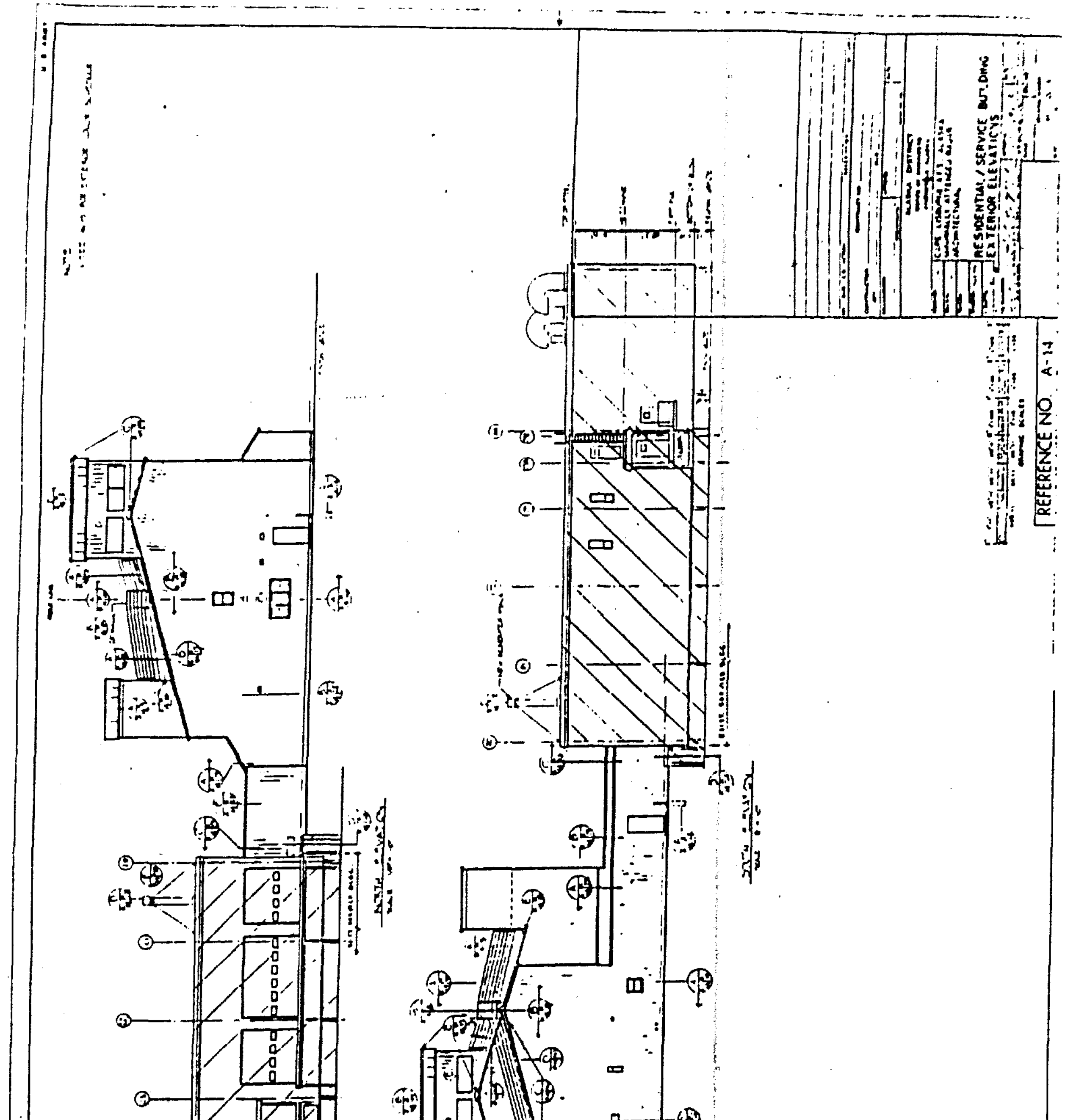
First Floor Residential Dome



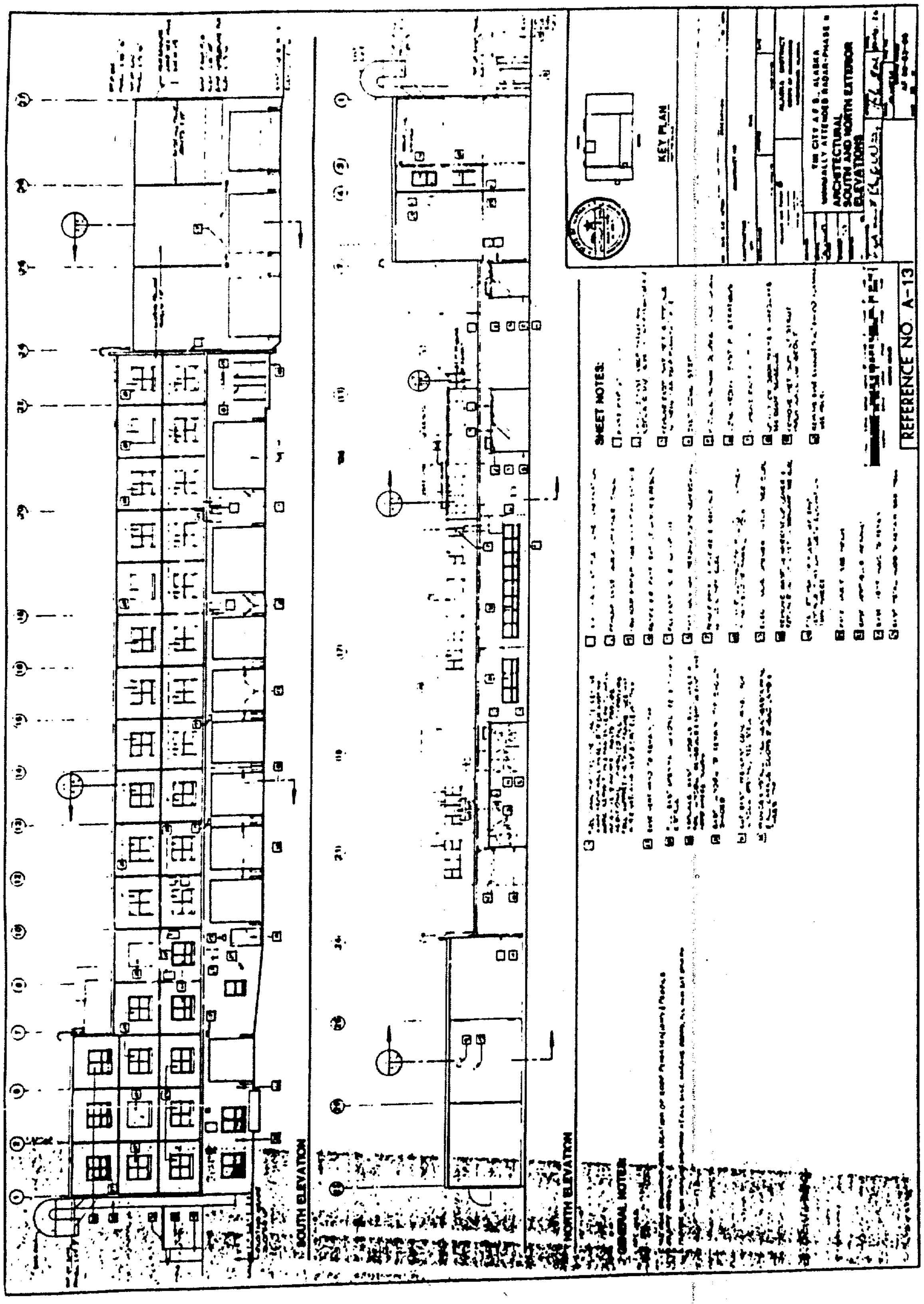
Second Floor Industrial Dome



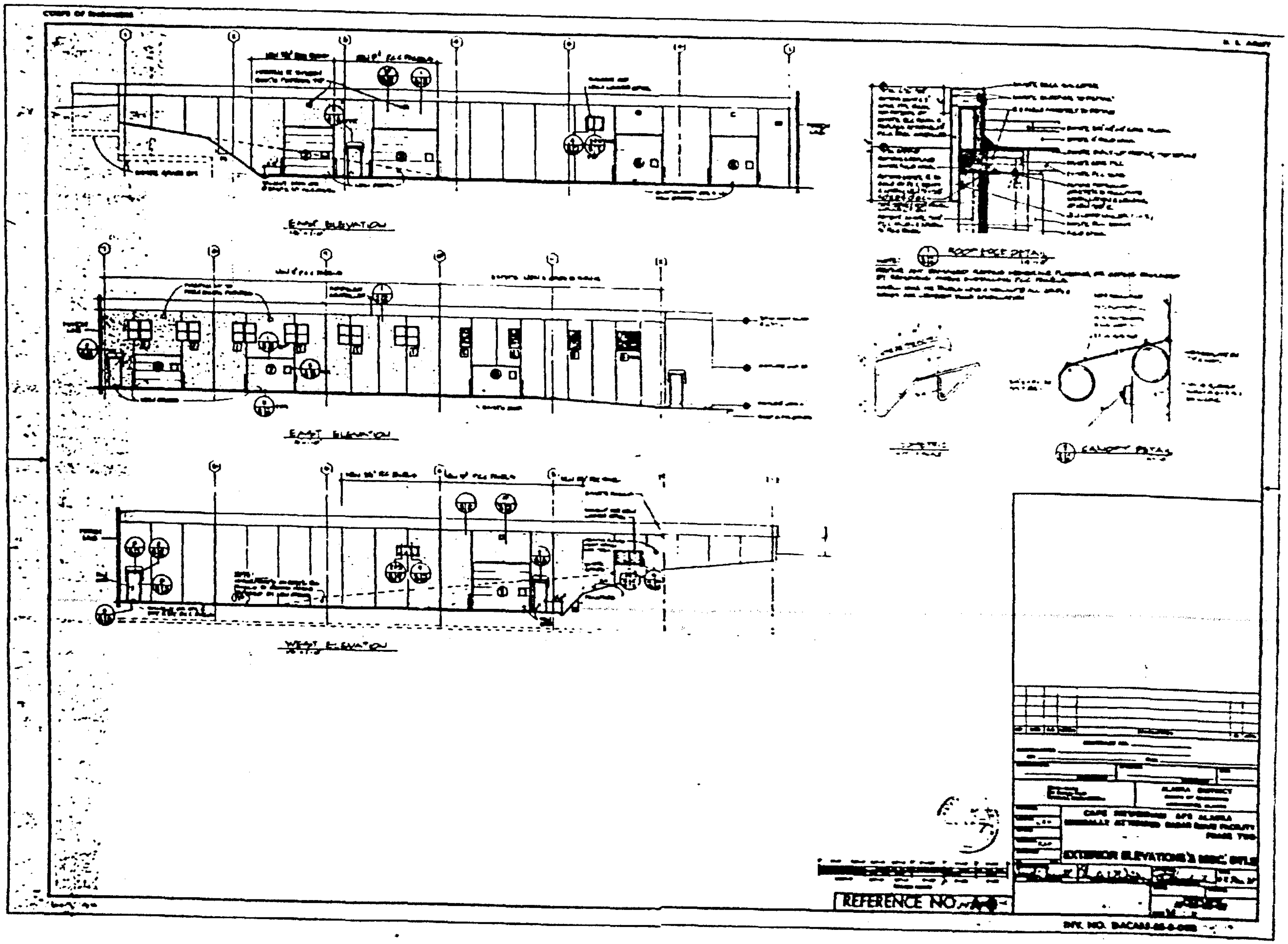
Phase II. Fort Yukon Structure Elevations



Phase II. Cape Lisburne Structure Elevations



Phase II. Tin City Structure Elevations



Phase II. Cape Newenham Structure Elevations

Appendix B

Diesel Engine
Generator and Heat Recovery
System Descriptions

APPENDIX B

DIESEL ENGINE GENERATOR AND HEAT RECOVERY SYSTEM DESCRIPTIONS

DIESEL ENGINE GENERATOR SET

KTA1150 Cummins engine and Kato generator combination capable of a one-step, 100 percent load pickup as required by MIL STD 608.1A, Paragraph 705.

Power Rating:

250 kW at 0.8 power factor, 60 Hz, 120/208V, 1200 RPM

Engine Specification:

In line 6 cylinder diesel turbocharged and after cooled, 1150 in^3 displacement, Brake Mean Effective Pressure = 209

Governor:

American Bosch Model AGD130E4/LSP672B electric governor with load sharing function mounted in switchgear

Generator:

Kato brushless AC generator Model 6P4-350S. 250 kW prime at 0.8 P.F., 3-phase, 4 wire, 60 Hz, 120/208 volts.
Exciter: Rotating rectifier
Voltage Regulator: Static, solid-state Basler SR4A with EMI suppression mounted in switchgear. Also, manual voltage control.

Circuit Breaker:

Westinghouse DS-416 generator circuit breakers, 1200A with long time, short time, instantaneous trips, electrically operated drawout, 120 VAC charge and close, 48 VDC shunt trip, 4A4B auxiliary contacts. Westinghouse DS-632 tie breaker, 2400A, with long time, short time, instantaneous trips, electrically operated drawout, 120 VAC charge and close, 48 VDC shunt trip, 4A4B auxiliary contacts.

Fuel Oil:

Fuel for the engines at the sites is Diesel Fuel Arctic, Chevron brand name JA50 (-50°F Pour Point). The engines are designed to run on both this fuel and No. 2 diesel within the following specifications.

Recommended Fuel Oil Properties

Viscosity (ASTM D-445)	1.3 to 5.8 CentiStoke [1.3 to 5.8 mm Per Second] at 104°F [40°C].
Cetane Number (ASTM D-613)	40 minimum except in cold weathered or in service with prolonged low loads, a higher cetane number is desirable.
Sulfur Content (ASTM D-129 or 1552)	Not to exceed 1% by weight.
Water and Sediment (ASTM D-1796)	Not to exceed 0.1% by weight.
Carbon Residue (Ransbottom ASTM D-524 or D-189)	Not to exceed 0.25% by weight on 10% residue.
Flash Point	125°F [52°C] minimum.
Density (ASTM D-287)	30 to 42°F [-1 to 6°C] A.P.I. at 60°F [16°C] (0.816 to 0.876 Sp. Gr.)
Cloud Point (ASTM D-97)	10°F below lowest ambient temperature expected.
Active Sulfur-Copper Strip-Corrosion (ASTM D-130)	Not to exceed No. 2 rating after 3 hours at 122°F [50°C].
Ash (ASTM D-482)	Not to exceed 0.02% by weight.
Distillation (ASTM D-86)	The distillation curve should be smooth and continuous. At least 90% of the fuel should evaporate at less than 680°F [360°C]. All of the fuel should evaporate at less than 725°F [385°C].

ENGINE COOLING AND SILENCING

Cooling:

Each unit is equipped with a Perfex Model C870-228AA heat recovery exchanger, Table B-1. Each pair of generator sets is equipped with a Perfex Model OVD17F-10 remote radiator, Table B-2.

Silencing:

Perfex Model AD5-36-STVR exhaust gas heat exchanger, Table B-3. 5-inch side inlet, 8-inch side outlet, 150# ASA flanges. Stainless steel exhaust flex section, 10-inch active, 5-inch, 125# ASA flange connection.

ENGINE MAINTENANCE

Scheduled maintenance is performed every 250 hours at the MAR facilities. The engines are rotated in and out of service on this basis with operating times of each engine kept as equal as possible. Table B-4 is Cummins' recommended maintenance schedule for continuous duty engine generator sets.

Table B-1. Heat Recovery Exchanger

DUTY		Heat Recovery Exchanger 20500	BTU/MIN. ~~(W)~~
SHELL SIDE—	FLUID	50% EG 50% Water	
	FLOW RATE	150	SCFM (m³/min.) GPM (l/min.)
	TEMP. IN	160	°F (°C)
	TEMP. OUT	178.6	°F (°C)
	PRESSURE DROP	7.9	PSI (Pa)
	FOULING	.0021 Total	hr °F ft²/BTU (°cm²/w)
TUBE SIDE—	FLUID	50% EG/50% Water	
	FLOW RATE	125	SCFM (m³/min.) GPM (l/min.)
	TEMP. IN	207.6	°F (°C)
	TEMP. OUT	185.3	°F (°C)
	PRESSURE DROP	3.4	PSI (Pa)
	FOULING	-	

PERFEX MODEL ______ DIA. 8.15 In (mm) LENGTH 75.4 In. (mm)

Table B-2. Remote Radiator Specification

Oval/Round Tube Radiator

Heat Load: 41,000 BTU/min (Ht. Load from Two Engines)

	Airside	Tubeside
Fluid:	Air	50% EG/50% H_2O
Flow:	25870 CFM	250 GPM
Temperature In:	55°F	207.6°F
Temperature Out:	145.4° F	185.3° F
Pressure Drop:	1.2 inches H_2O	1.4 PSI

Application: Dump Radiator - For use when heat process not being utilized.

Dry Weight: 1300 lb. Capacity: 19.8 gal.

Overall Width: 59.1 in. Height: 65.0 in. Depth: 34.2 in.

Inlet Size/Quantity: 1 / 4 in. - 8 NPTF

Outlet Size/Quantity: 1 / 4 in. - 8 NPTF

dBa at 3 ft.: 104 dBA, at 25 ft.: 86

Motor, HP: 10 PH: 3 HZ: 60 volts: 230 / 460

RPM: 1160 Style: TEFC

Frame Size: 256T

Table B-3. Exhaust Gas Heat Exchanger

DUTY		Exhaust Gas Heat Exchanger 9462	BTU/MIN. XXX
SHELL SIDE—	FLUID	50% EG/50% Water	
	FLOW RATE	125	SCFM (m^3/min.) GPM (l/min.)
	TEMP. IN	197	°F (°C)
	TEMP. OUT	207.6	°F (°C)
	PRESSURE DROP	.4	PSI (Pa)
	FOULING	.0015 Total	hr °F ft²/BTU (°cm²/w)
TUBE SIDE—	FLUID	Exhaust Gas	
	FLOW RATE	2200	SCFM (m^3/min.) XXXXXXXXX
	TEMP. IN	1000	°F (°C)
	TEMP. OUT	362	°F (°C)
	PRESSURE DROP	6.6	PSI (Pa)
	FOULING	-	

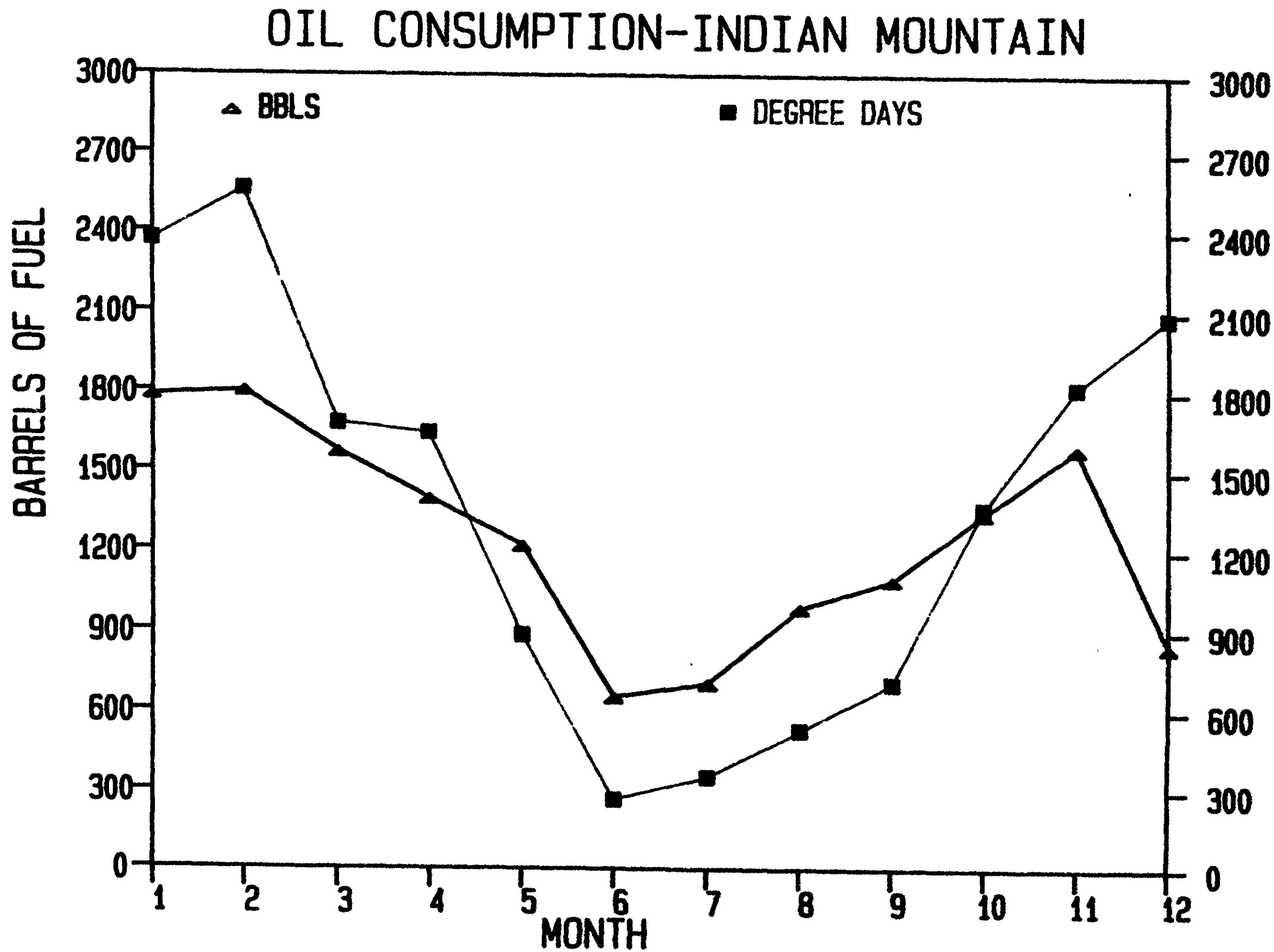
PERFEX MODEL ______ DIA. 12.75 In. (mm) LENGTH 49.8 In (mm)

Table B-4. Cummins Recommended Maintenance Schedule

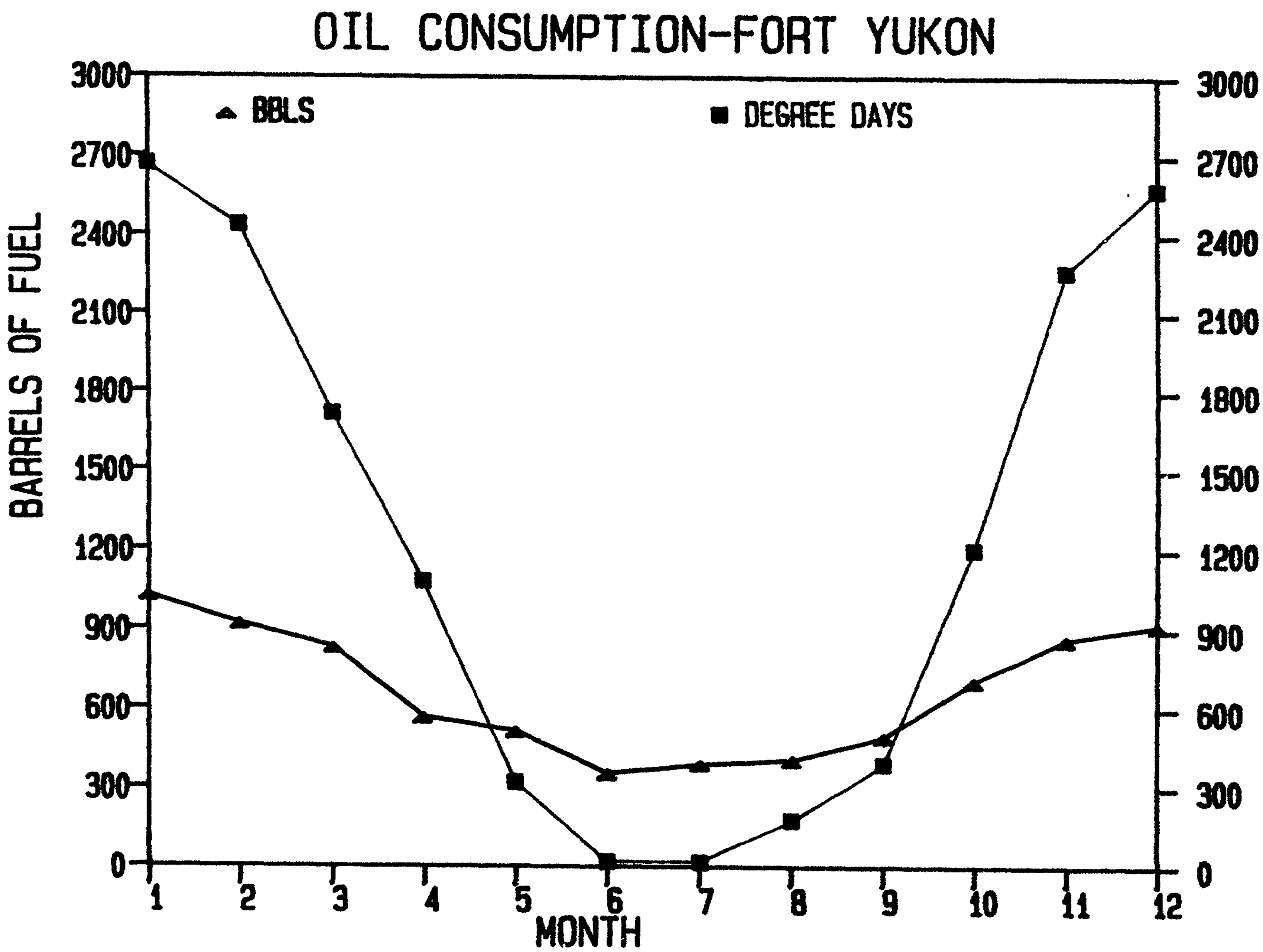
Engine Systems			Daily	6 Mos 250 Hrs	1 Year 1500 Hrs	2 Years 4500 Hrs	Annually
Lubricating	Check:	– For Leaks	●	●	●	●	●
		– Operation of Oil Heater					●
		– Engine Oil Level	●	●	●	●	●
		– Hydraulic Governor Oil Level	●	●	●	●	●
	Change:	– Full Flow Filter		●	●	●	●
		– By-Pass Filter		●	●	●	●
		– Engine Oil		●	●	●	●
		– Hydraulic Governor Oil		●	●	●	●
Cooling	Check:	– For Leaks	●	●	●	●	●
		– For Radiator Air Restriction	●	●	●	●	●
		– Operation of Coolant Heater					●
		– Hose and Connections	●	●	●	●	●
		– Coolant Level	●	●	●	●	●
		– Anti-Freeze and DCA Concentration		●	●	●	●
		– Belt Condition and Tension	●	●	●	●	●
		– Fan Hub, Drive Pulley, and Water Pump		●	●	●	●
		– Heat Exchanger Zinc Anode Plugs					●
	Change:	– DCA Water Filter		●	●	●	●
	Clean:	– Cooling System					●
Air Intake	Check:	– For Leaks	●	●	●	●	●
		– Air Cleaner Restriction	●	●	●	●	●
		– Piping and Connections		●	●	●	●
	Clean:	– Crankcase Breather		●	●	●	●
		– Or Change Air Cleaner Element		●	●	●	●
Fuel	Check:	– For Leaks	●	●	●	●	●
		– Governor Linkage		●	●	●	●
		– Fuel Lines and Connections		●	●	●	●
	Drain:	– Sediment from Tanks	●	●	●	●	●
	Change:	– Fuel Filters		●	●	●	●
	Clean:	– Fuel Tank Breather		●	●	●	●
		– and Calibrate Injectors				●	
		– and/or Calibrate Fuel Pump				●	
		Adjust Injectors and Valves			●	●	
Exhaust	Check:	– For Leaks	●	●	●	●	●
		– For Exhaust Restriction			●	●	
	Clean:	– Turbocharger Comp. Wheel and Diffuser				●	
	Check:	– Turbocharger Bearing Clearance				●	
		– Torque Exhaust Manifold and Turbocharger Capscrews			●	●	
Engine Related	Check:	– For Unusual Vibration	●	●	●	●	●
		– Vibration Damper				●	
		– Crankshaft End Play				●	
		Tighten Mounting Hardware				●	
	Clean:	– Engine					●
	Grease:	– Fan Pillow Block Bearings		●	●	●	●
Electrical	Check:	– Battery Charging System					●
		– Battery Electrolyte Level					
		Specific Gravity		●	●	●	●
		– Glow Plug					●
		– And Clean Magnetic Pickup Unit			●	●	
		– Safety Control and Alarms			●	●	
Main Generator	Check:	– Air Inlet and Outlet for Restriction	●	●	●	●	●
		– Windings and Electrical Connections	●	●	●	●	●
		– Operation of Generator Heater Strips					●
	Grease:	– Bearing			●	●	
	Clean:	– Generator					●
Switchgear	Check	– Power Distribution Wiring and Connections	●	●	●	●	●
		– Power Circuit Breaker			●	●	
		– Transfer Switch			●	●	

Appendix C

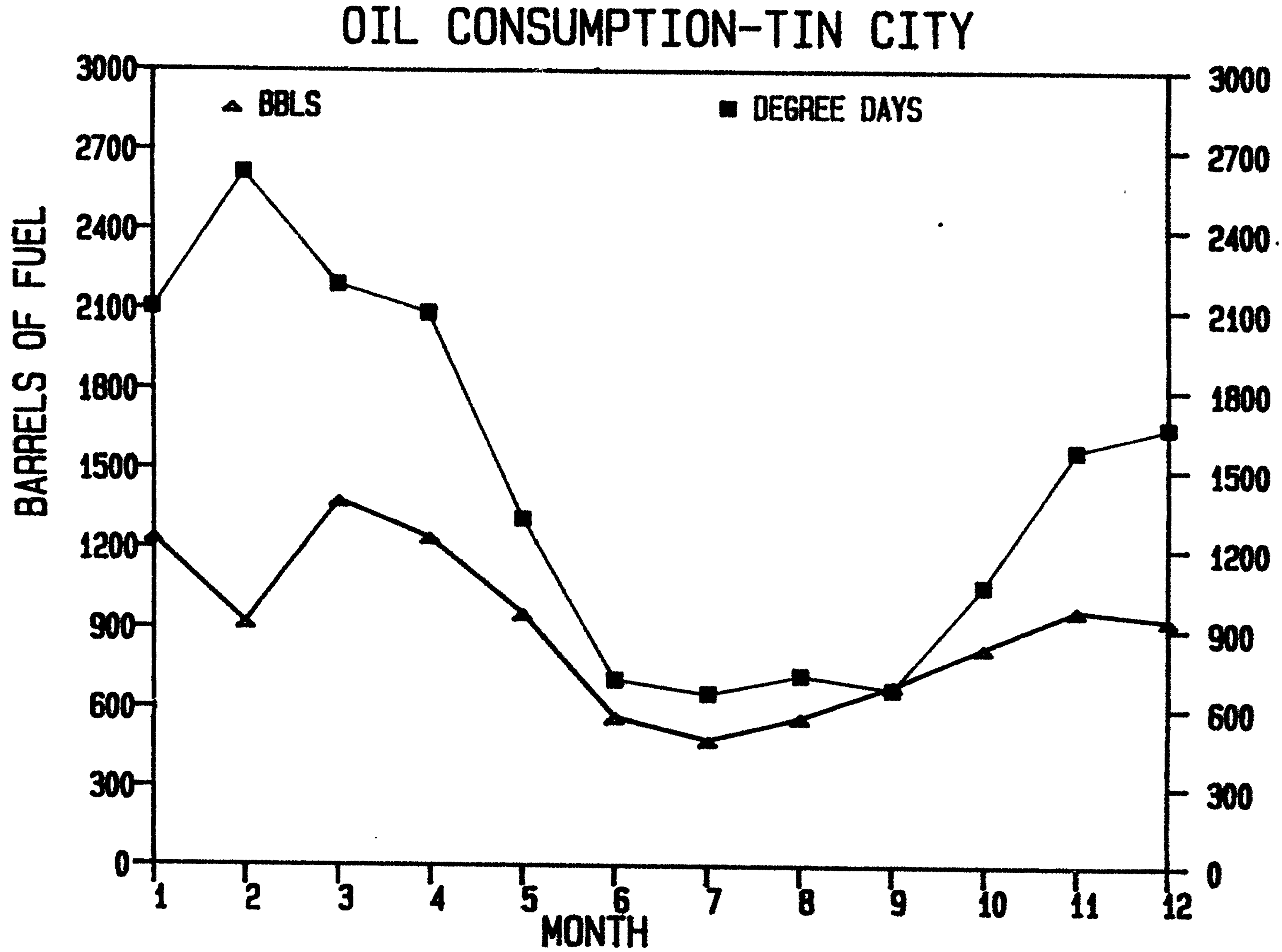
Pre-Conversion Oil Consumption Data 1984



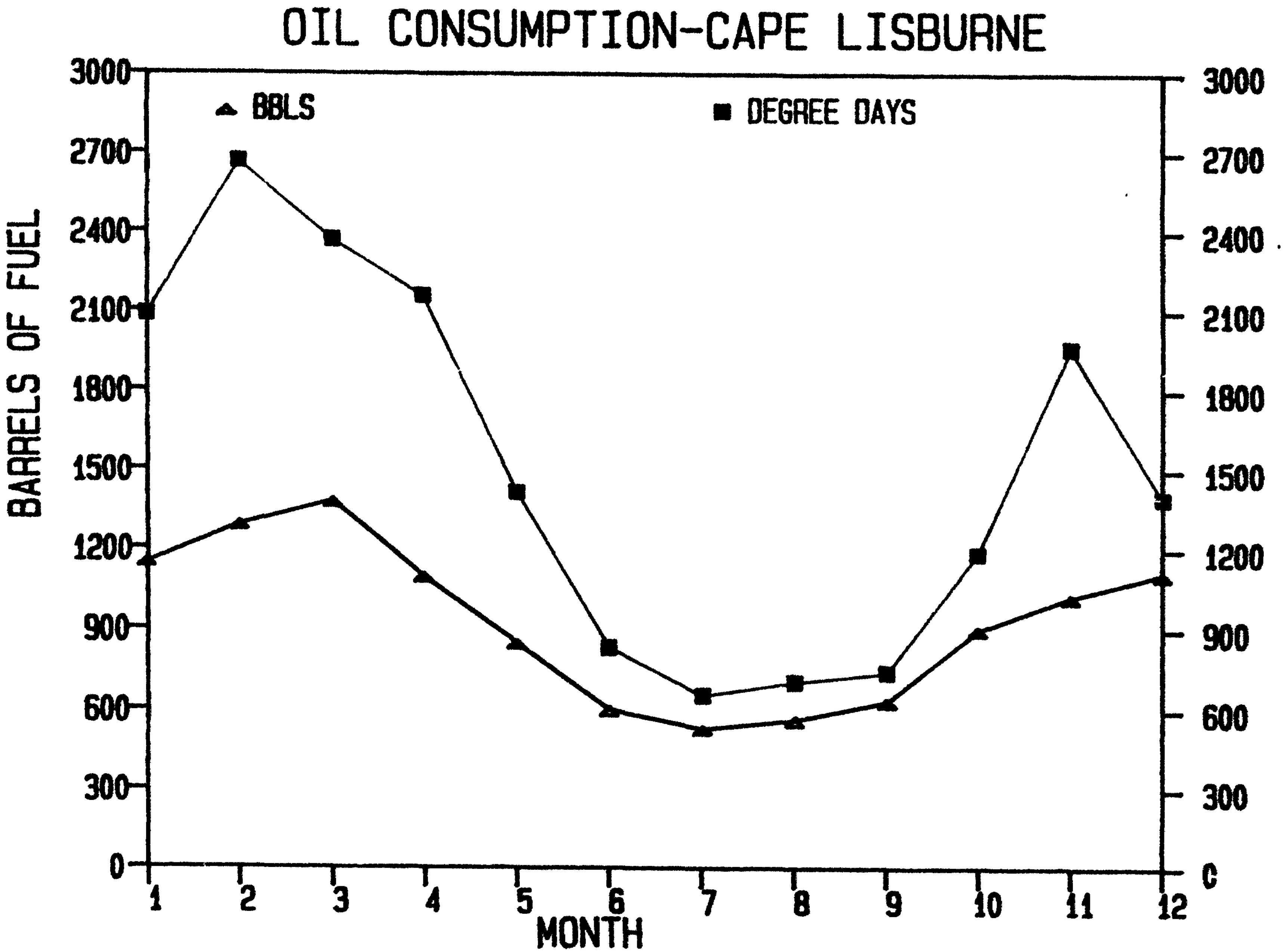
Oil Consumption - Indian Mountain (12/84 is MAR Site Data)



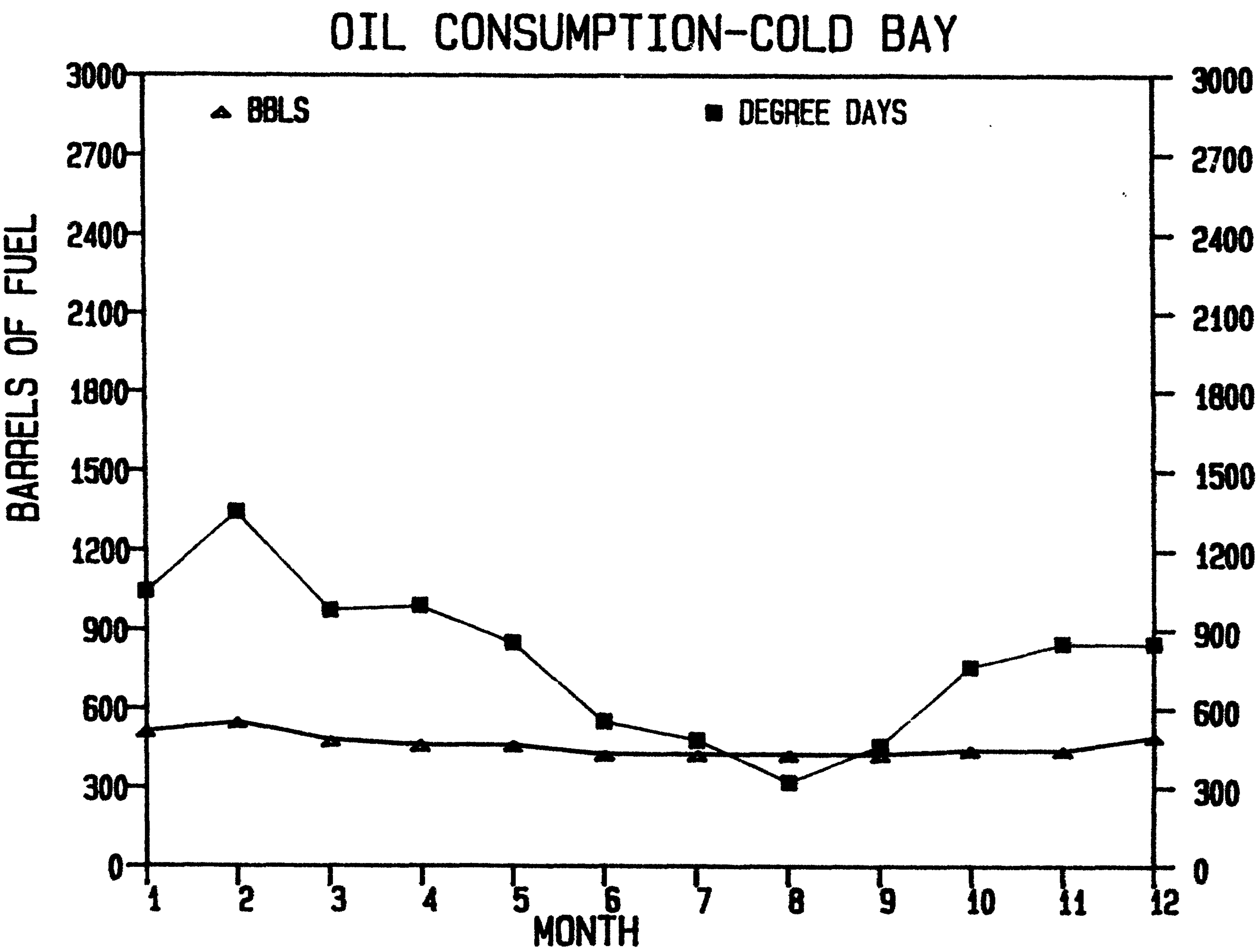
Oil Consumption - Fort Yukon



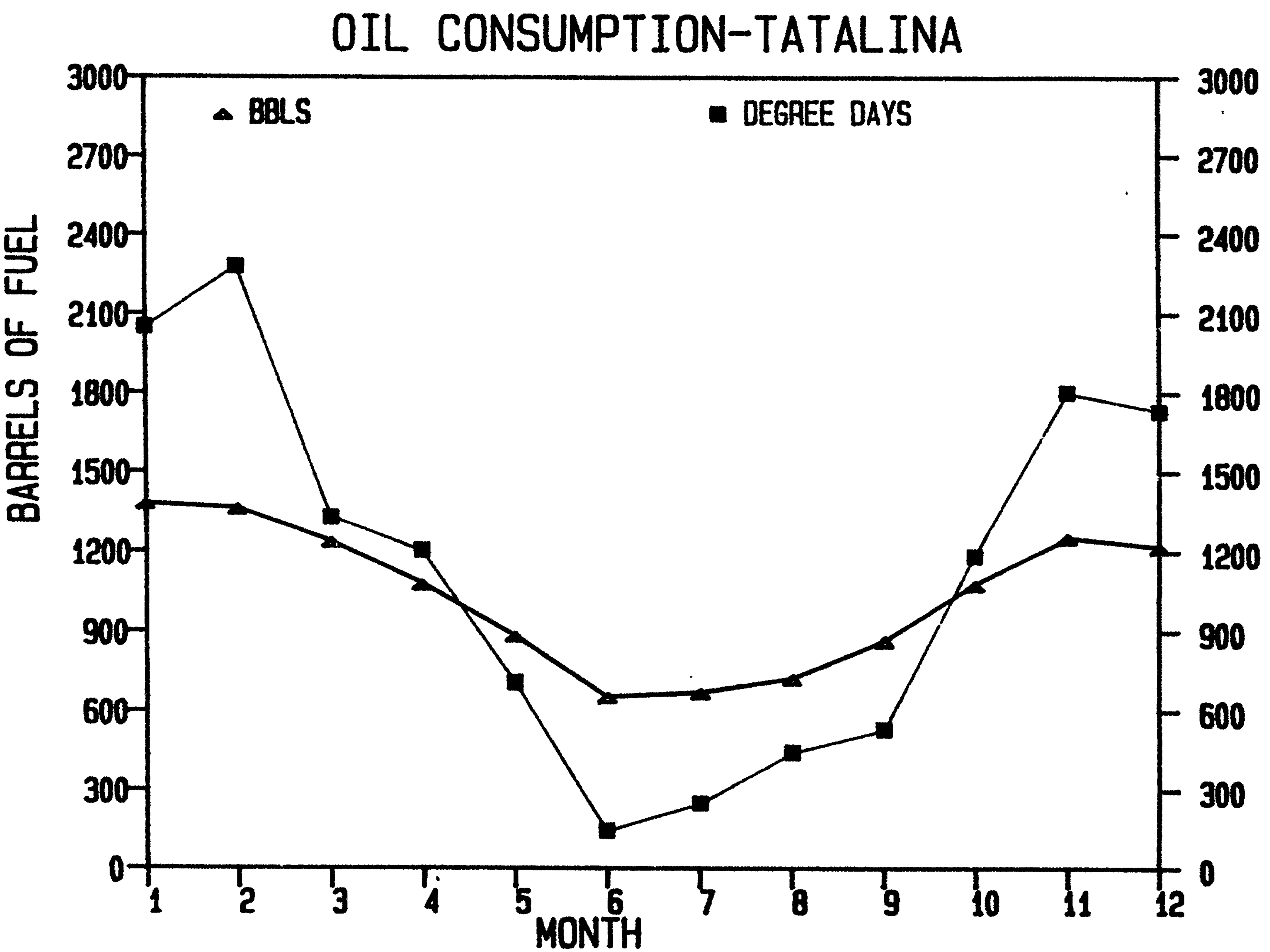
Oil Consumption - Tin City



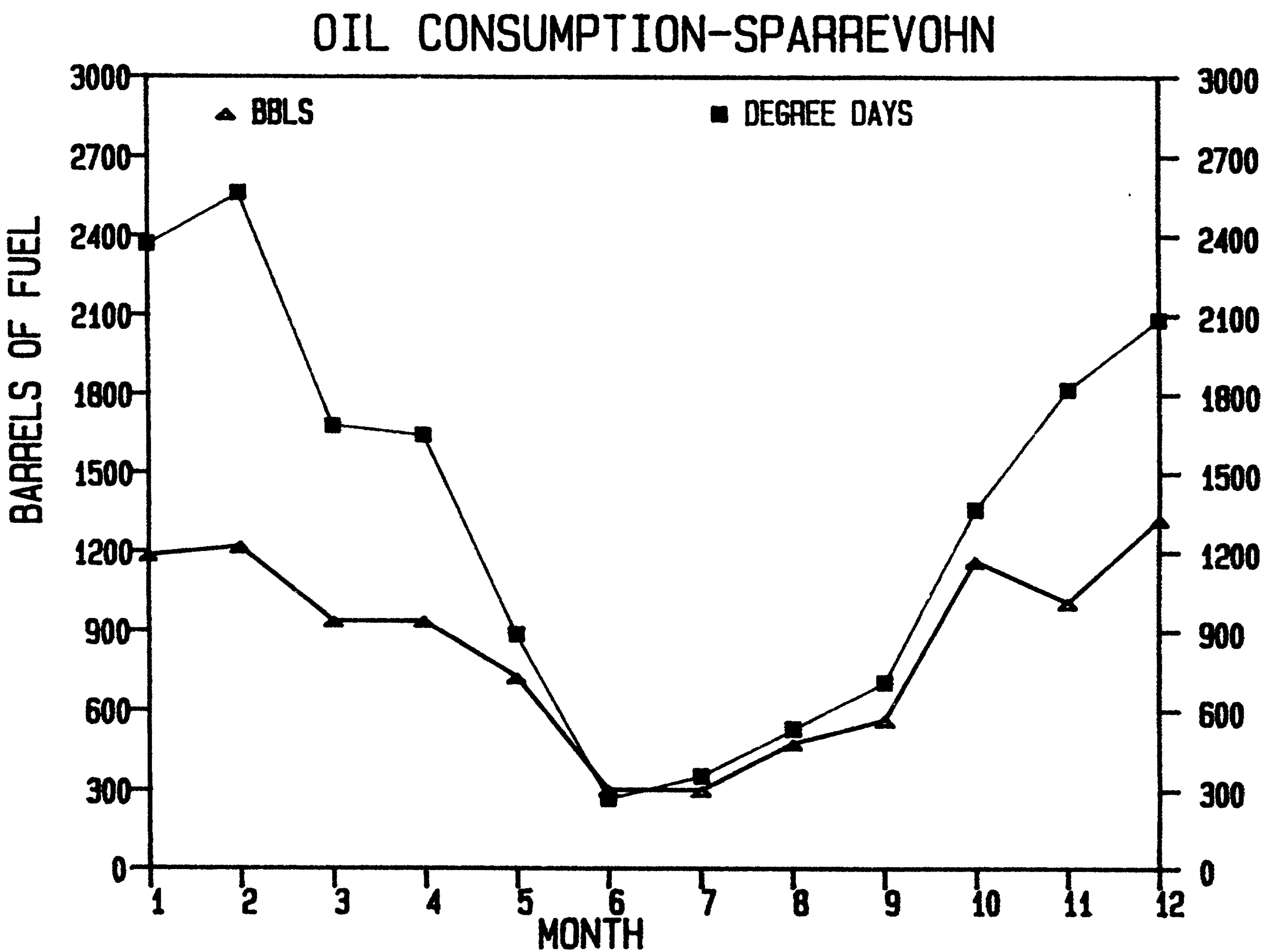
Oil Consumption - Cape Lisburne



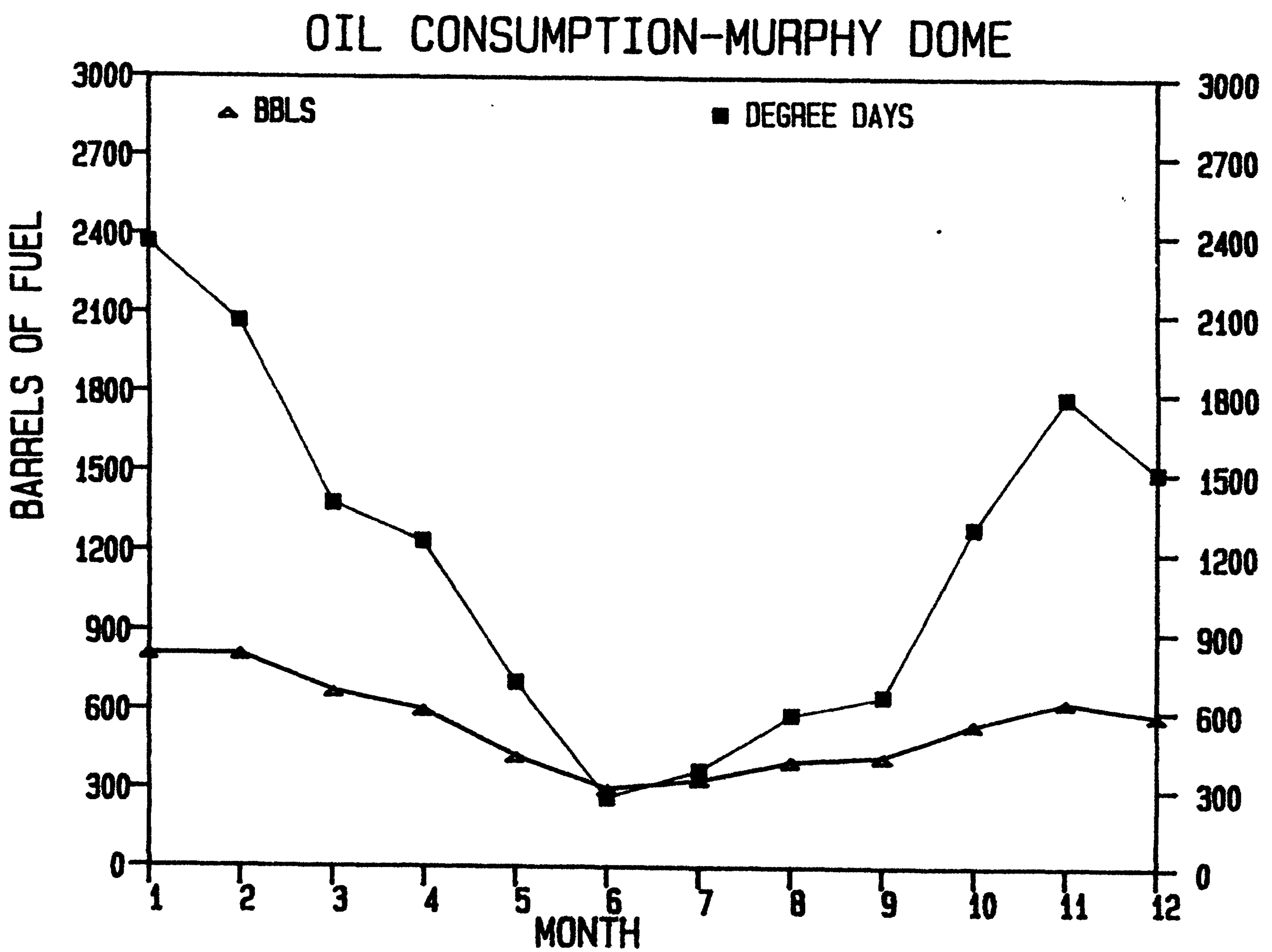
Oil Consumption - Cold Bay



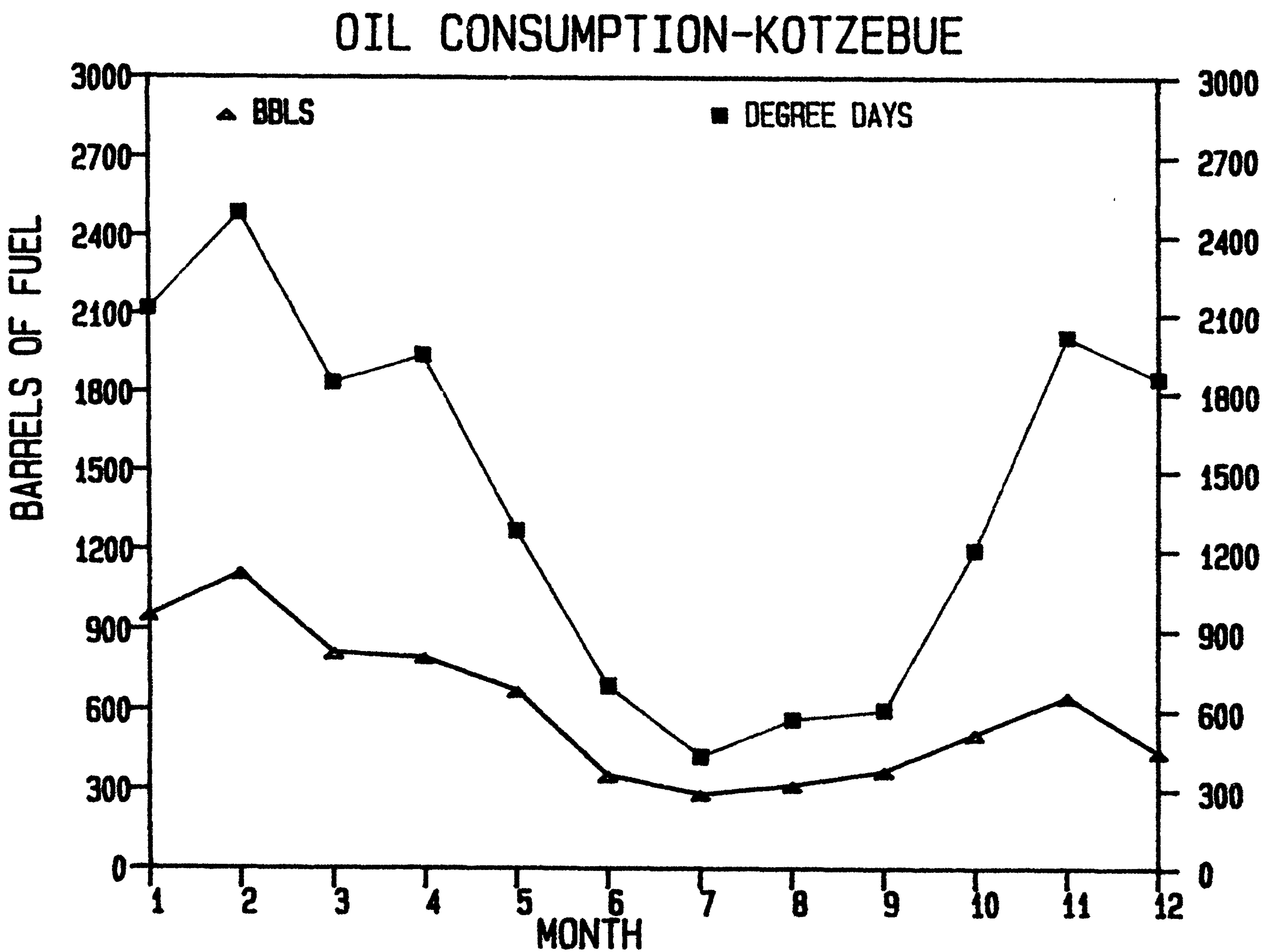
Oil Consumption - Tatalina



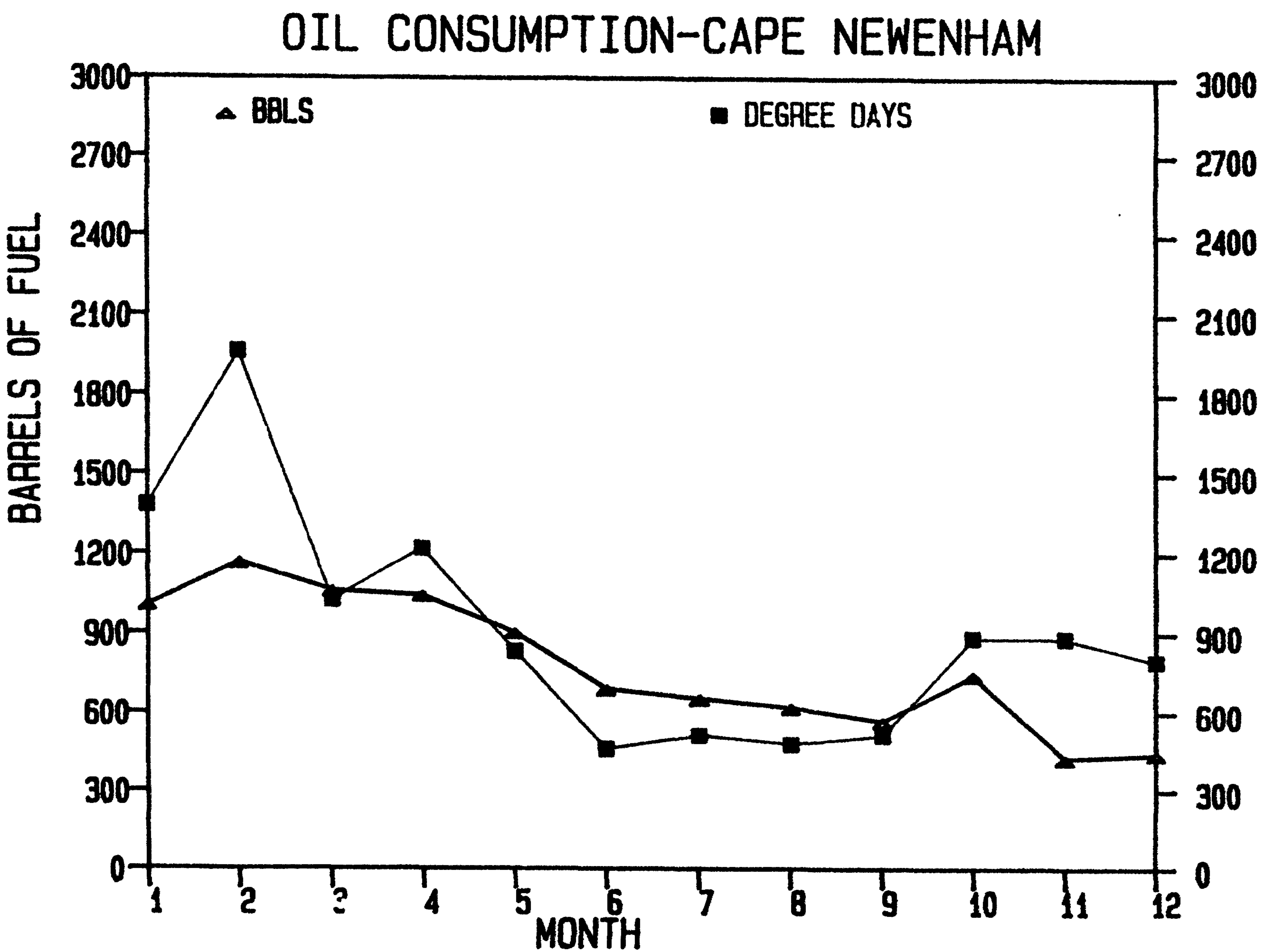
Oil Consumption - Sparrevohn



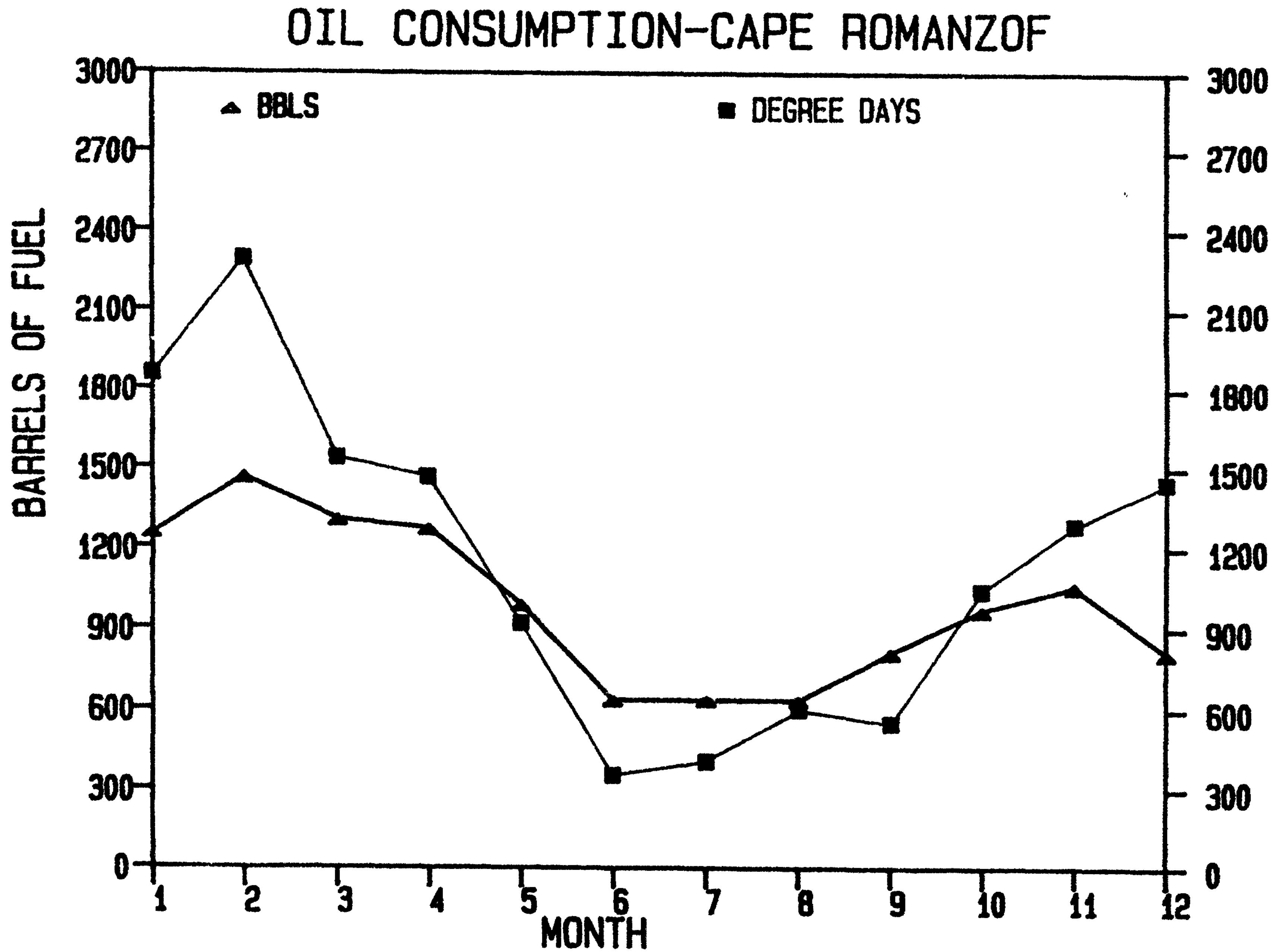
Oil Consumption - Murphy Dome



Oil Consumption - Kotzebue



Oil Consumption - Cape Newenham (2/84-12/84 is MAR site data)



Oil Consumption - Cape Romanzof

Appendix D

Remote Sites
Energy Data Sheets

GLOSSARY OF TERMS

Degree Days - The degree days per month are the summation of the daily average ambient temperatures in °F minus 65°F. Only positive temperature differences are included.

Electrical Demand - The maximum, average, and minimum kW demands are reported monthly in the CDRL III-B-2 form. The monthly average value is the average of these reported values. The annual value for the maximum demand is the highest of the reported monthly values.

Electrical Efficiency (kWh/Gal) - The monthly site electrical efficiency is calculated in kWh/gal by the following equation:

$$\text{Efficiency} = \frac{\text{site kWh generation per month}}{\text{fuel consumption of engines per month (gal)}}$$

The annual efficiency is calculated using annual kWh and fuel consumption.

Electrical Efficiency (%) - The monthly site electrical efficiency is calculated as follows:

$$\text{Efficiency (\%)} = \frac{\text{site kWh/month x 3412 Btu/kWh}}{\text{monthly engine fuel consumption (gal) x HHV (138,700 Btu/gal)}}$$

The annual efficiency is calculated using annual kWh and fuel consumption.

Engine Hours - The engine hours are the total engine run time per month including part load operation.

Heat Rate - The monthly heat rate (Btu/kWh) is calculated using the following equation:

$$\text{Heat Rate (Btu/kWh)} = \frac{\text{engine fuel consumption per month (gal)} \times \text{HHV (138,700Btu/gal)}}{\text{site kWh generation per month}}$$

The annual values for the heat rate are calculated using annual totals for fuel consumption and site kWh generation.

Site Capacity Factors (SCF) - The SCF represents the degree to which the electric generating equipment's capacity is actually used. The monthly SCF is calculated by the following equation.

$$\text{Monthly SCF} = \frac{\text{site kWh generation per month}}{\text{total rated output at site (kW)} \times \text{hours per month}}$$

The annual value of the SCF is calculated by the following equation:

$$\text{Annual SCF} = \frac{\text{site kWh generation per year}}{\text{total rated output at site (kW)} \times \text{hours per year (h)}}$$

Site Load Factor (SLF) - The SLF represents the consistency of site electrical loads. The SLF is calculated on a monthly basis by the following equation:

$$\text{SLF} = \frac{\text{site kWh generation per month}}{\text{maximum demand (kW)} \times \text{hours per month}}$$

The averge monthly value of the SLF is calculated by the following equation:

$$\text{SLF (avg. mo. value)} = \frac{\text{monthly average site kWh generation}}{\text{monthly average max demand (kW)} \times \text{average days per mo.} \times \text{24 hr/day}}$$

The annual value of the SLF is calculated by the following equation:

$$\text{SLF (annual value)} = \frac{\text{site kWh generation per year}}{\text{annual maximum demand (kW)} \times \text{hours per year}}$$

Typical Engine Rate (TER) - The TER is the capacity factor of only those engines that were actually operating for the month. The monthly TER is calculated by the following equation:

$$\text{TER (monthly)} = \frac{\text{site kWh generation per month}}{\text{SUM [rated engine output (kW)} \times \text{engine run time per month (h)]}}$$

where SUM [.......] signifies a summation of each of the engines at a site. The annual value of the TER is calculated by:

$$\text{TER (annual value)} = \frac{\text{site kWh generation per year}}{\text{SUM [rated engine output (kW)} \times \text{engine run time per yr (h)]}}$$

ALASKAN REMOTE SITE ENERGY DATA FOR 1985

INDIAN MOUNTIAN - PHASE 1 *

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Monthly Value **	Annual Value **
Site Conversion Status	MAR	MAR	MAR	MAR	MAR	MAR	MAR	MAR	MAR	MAR	MAR	MAR		
Fuel Consumption (Gallons)														
Engine	19861	20492	17910	16635	11898	10934	11403	10500	10979	13230	12974	12716	14128	169532
Boiler	24766	6934	1419	0	0	0	0	0	0	0	0	0	2760	33119
Total	44627	27426	19329	16635	11898	10934	11403	10500	10979	13230	12974	12716	16888	202651
Electricity Production														
Generation (kWh)	250350	241080	218225	198516	173040	188825	171072	151500	155150	198264	191391	204400	195151	2341813
Maximum Demand (kW)	155	155	155	155	128	140	130	111	123	298	298	280	177	298
Average Demand (kW)	148	145	145	142	112	110	108	101	107	264	263	257	159	
Minimum Demand (kW)	140	135	135	135	89	85	80	92	98	220	234	230	140	80
Efficiency (kWh/gal)	12.61	11.76	12.18	11.93	14.54	17.27	15.00	14.43	14.13	14.99	14.75	16.07		13.81
Efficiency (%) +	0.31	0.29	0.30	0.29	0.36	0.42	0.37	0.35	0.35	0.37	0.36	0.40		0.34
Heat Rate (Btu/kWh) +	11003	11790	11383	11623	9537	8031	9245	9613	9815	9255	9402	8629		10041
Operaration Parameters														
Engine Run Time (Hours)														
Cum 31123249 (175 kW) ++	686	439	411	356	255	344	453	538	374	403	579	532	464	5570
Cum 31128021 (175 kW)	430	151	278	321	471	325	496	312	402	249	361	529	360	4325
Cum 31128020 (175 kW)	225	533	354	265	349	375	341	384	408	401	12	171	318	3818
Cum 31128015 (175 kW)	328	599	462	456	470	263	294	266	266	249	509	228	366	4390
Engine Hours	1669	1722	1505	1398	1545	1307	1584	1500	1450	1502	1461	1460	1509	18103
Total Engine Hours														
Cum 31123249 (175 kW)	1794	2233	2619	300	3255	3599	4092	4630	5004	5607	6189	6718		
Cum 31128021 (175 kW)	1709	1860	2113	2459	2930	3255	3751	4063	4465	4714	5075	5604		
Cum 31128020 (175 kW)	1542	2075	2429	2694	3043	3418	3806	4190	4598	4999	5011	5182		
Cum 31128015 (175 kW)	1455	2054	2515	2972	3442	3703	3975	4241	4507	4756	5265	5493		
Engine kWh Generation #														
Cum 31123249 (175 kW)	102900	61460	59595	50552	28560	49698	48924	54338	40018	79596	79596	79596		734833
Cum 31128021 (175 kW)	64500	21140	40310	45582	52752	46953	53568	31512	43014	32868	32868	32868		497935
Cum 31128020 (175 kW)	33750	74620	51330	37630	39088	54177	36828	38784	43656	52932	52932	52932		568659
Cum 31128015 (175 kW)	49200	83860	66990	64752	52640	37996	31752	26866	28462	32868	32868	32868		541122
Total kWh	250350	241080	218225	198516	173040	188825	171072	151500	155150	198264	191391	204400		2341813
System Capacity Factor	0.48	0.51	0.42	0.39	0.33	0.37	0.33	0.29	0.31	0.39	0.38	0.41		0.38

Typical Engine Rate	##	0.86	0.80	0.83	0.81	0.64	0.83	0.62	0.58	0.61	0.75	0.75	0.80		0.74
Site Load Factor	'	2.17	2.31	1.89	1.78	1.82	1.87	1.77	1.83	1.75	0.89	0.89	0.98	1.51	0.90
Costs															
Diesel Engine Fuel Cost		25621	26434	23104	21459	15348	14105	14709	13500	17066	17066	16736	16403	18463	221551
Lube Oil Cost		343	233	248	303	303	303	419	362	304	305	433	303	322	3859
Site Maintenance Cost		828	552	575	828	1564	920	1219	1104	690	690	966	552	874	10488
Site Material Cost		558	372	430	559	565	552	1780	697	697	581	814	464	672	8069
Labor Operating Cost		690	690	1564	2116	2116	2208	2185	1679	1518	1196	1150	1150	1522	18262
		-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Diesel Engine Operating Cost		28040	28281	25921	25265	19896	18088	20312	17342	20275	19838	20099	18872	21852	262229
Additional Heating Cost		31948	8945	1831	0	0	0	0	0	0	0	0	0	[illegible]	42724
		-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Total Site Energy Cost		59988	37226	27752	25265	19896	18088	20312	17342	20275	19838	20099	18872	25413	304953
Degree Days		1672	2110	1229	1248	812	478	414	403	435	369	1718		989	10880

* The site conversion status is indicated by MAR = site after conversion, TRANS = site during the LRRS/MAR site transition, and LRRS = site before conversion. The MAR equipment became fully operational in September 1984.

+ These values are calculated by assuming a higher heating value of 138700 Btu/gallon of diesel fuel.

++ The Cummins 31123249 was replaced by Cummins 31128049 in March 1985.

These values are estimated.

This estimate is monthly kWh divided by the engine hours and by 175 kW.

' The load factor which is calculated for this site is unreasonable. The reported kW demand data for January through September appears to be erroneous. The monthly load factor is the total kWh divided by the peak demand and by the numbers of hours in the month.

ALASKAN REMOTE SITE ENERGY DATA FOR 1985

SPARREVOHN - PHASE I *

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Monthly Value **	Annual Value **
Site Conversion Status	MAR	MAR	MAR	MAR	MAR	MAR	MAR	MAR	MAR	MAR	MAR	MAR		
Fuel Consumption (Gallons)														
Engine	12822	13640	13313	13485	11925	11215	11260	11685	11810	13015	11092	10984	12187	146246
Boiler	0	1610	4503	0	0	0	0	0	0	125	2079	547	739	8864
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Total	12822	15250	17816	13485	11925	11215	11260	11685	11810	13140	13171	11531	12926	155110
Electricity Production														
Generation (kWh)	166320	187920	184080	190800	171360	154800	153600	158640	164160	179040	150348	146160	167269	2007228
Maximum Demand (kW)	280	390	360	350	275	275	240	245	260	325	250	240	291	390
Average Demand (kW)	224	280	247	265	230	215	206	213	228	246	209	215	231	
Minimum Demand (kW)	200	230	215	225	195	180	160	205	210	210	190	195	201	160
Efficiency (kWh/gal)	12.97	13.78	13.83	14.15	14.37	13.80	13.64	13.58	13.90	13.70	13.55	13.31		13.73
Efficiency (%) +	0.32	0.34	0.34	0.35	0.35	0.34	0.34	0.33	0.34	0.34	0.33	0.33		0.34
Heat Rate (Btu/kWh) +	10693	10067	10031	9803	9652	10049	10168	10216	9978	10124	10236	10421		10106
Operaration Parameters														
Engine Run Time (Hours)														
Cum 31128017 (175 kW)	37	9	155	652	682	584	601	615	693	383	305	426	429	5142
Cum 31128018 (175 kW)	541	410	467	290	287	268	354	272	251	300	450	416	359	4306
Cum 31127987 (175 kW)	413	556	440	290	265	307	290	338	237	423	323	380	355	4262
Cum 31123569 (175 kW)	515	509	456	257	288	294	291	268	294	394	361	353	357	4280
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Engine Hours	1506	1484	1518	1489	1522	1453	1536	1493	1475	1500	1439	1575	1499	17990
Total Engine Hours														
Cum 31128017 (175 kW)	461	472	626	1282	1964	2548	3149	3764	4457	4840	5145	5584		
Cum 31128018 (175 kW)	1839	2251	2718	3409	3297	3565	3919	4191	4442	4742	5192	5534		
Cum 31127987 (175 kW)	1740	2298	2740	3031	3274	3581	3871	4208	4445	4868	5191	5599		
Cum 31123569 (175 kW)	1790	2289	2748	3007	3297	3591	3882	4150	4444	4838	5199	5515		
Engine kWh Generation ++														
Cum 31128017 (175 kW)	4086	1140	18796	83547	76785	62218	60100	65347	77127	45715	31867	39533		566262
Cum 31128018 (175 kW)	59747	51919	56631	37161	32313	28552	35400	28902	27935	35808	47016	38605		479988
Cum 31127987 (175 kW)	45611	70407	53357	37161	29836	32707	29000	35914	26377	50489	33747	35264		479870
Cum 31123569 (175 kW)	56876	64455	55297	32932	32426	31322	29100	28477	32721	47028	37718	32758		481108
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Total kWh	166320	187920	184080	190800	171360	154800	153600	158640	164160	179040	150348	146160		2007228
Site Capacity Factor ++	0.32	0.40	0.35	0.38	0.33	0.31	0.29	0.30	0.33	0.36	0.30	0.29		0.33

Typical Engine Rate	#	0.63	0.72	0.69	0.73	0.64	0.61	0.57	0.61	0.64	0.68	0.60	0.53		0.64
Site Load Factor	##	0.80	0.72	0.69	0.76	0.84	0.78	0.86	0.87	0.88	0.77	0.84	0.85	0.79	0.59
Costs															
Diesel Engine Fuel Cost		16540	17595	17174	17395	15383	14467	14525	15074	15235	16789	14308	14169	15721	188654
Lube Oil Cost		143	143	171	343	335	287	239	239	287	335	239	383	262	3144
Site Maintenance Cost		552	345	414	483	644	552	667	529	552	1196	460	736	594	7130
Site Material Cost		431	431	518	637	766	633	537	530	633	775	686	884	622	7461
Labor Operating Cost		1725	1587	1725	1587	1495	1518	1472	1610	1518	943	1610	1403	1516	18193
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Diesel Engine Operating Cost		19391	20101	20002	20445	18623	17457	17440	17982	18225	20038	17303	17575	18715	224582
Additional Heating Cost		0	2077	5809	0	0	0	0	0	0	161	2682	706	953	11435
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Total Site Energy Cost		19391	22178	25811	20445	18623	17457	17440	17982	18225	20199	19985	18281	19668	236016
Degree Days		1110	1769	1440	1432	784	427	241	432	704	1426	1364	1097	1019	12226

* The site conversion status is indicated by MAR = sites after conversion, TRANS = sites during LRRS/MAR site transition, and LRRS = sites before transition.
The MAR site became fully operational in September 1984.

** Values in these columns are discussed in the text and the glossary for Appendix D.

\+ These values are calculated by assuming a higher heating value of 138700 Btu/gallon of diesel fuel.

++ These values are estimated.

\# This estimate is monthly kWh divided by the engine hours and by 175 kW.

\## The monthly load factor is the kWh divided by the peak demand and by the hours in the month.

ALASKAN REMOTE SITE ENERGY DATA FOR 1985

TATALINA - PHASE 1 *

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Monthly Value **	Annual Value **
Site Conversion Status	TRANS	TRANS	TRANS	MAR	MAR	MAR	MAR	MAR	MAR	MAR	MAR	MAR		
Fuel Consumption (Gallons)														
Engine	44	44	1	14814	16330	13719	12450	12765	12155	12810	11260	14150	13384	120453
Boiler	20921	20974	22917	13502	12312	0	2097	0	0	0	0	0	3101	27911
Total	20965	21018	22918	28316	28642	13719	14547	12765	12155	12810	11260	14150	16485	148364
Electricity Production ***														
Generation (kWh)	0	0	0	215112	255404	193200	155760	170942	170317	184320	204480	216240	196197	1765775
Efficiency (kWh/gal)				14.52	15.64	14.08	12.51	13.39	14.01	14.38	14.89	15.28		14.66
Efficiency (%) +				0.36	0.38	0.35	0.31	0.33	0.34	0.35	0.37	0.38		0.36
Heat Rate (Btu/kWh) +				9552	8868	9849	11086	10357	9899	9645	9315	9077		9461
Operaration Parameters														
Engine Run Time (Hours)														
Cum 31123571 (175 kW)	1	1		456	547	247	694	554	568	747	724	746	587	5283
Cum 31123251 (175 kW)	1	1		552	426	708	445	379	212	0	0	0	302	2722
Cum 31123250 (175 kW)	1	1		576	688	482	479	503	246	745	721	739	575	5179
Cum 31122570 (175 kW)	1	1		576	582	718	601	435	446	73	18	14	385	3463
Engine Hours	4	4		2160	2243	2155	2219	1871	1472	1565	1463	1499	1850	16647
Total Engine Hours														
Cum 31123571 (175 kW)	282	283		999	1543	1790	2484	3038	3606	4353	5077	5823		
Cum 31123251 (175 kW)	304	305		1341	1857	2565	3010	3389	3601	3601	3601	3601		
Cum 31123250 (175 kW)	330	331		1420	2103	2585	3064	3567	3813	4558	5279	6018		
Cum 31122570 (175 kW)	294	295		1208	1783	2501	3102	3537	4033	4106	4124	4138		
Engine kWh Generation ++														
Cum 31123571 (175 kW)				45413	62285	22144	48714	50616	65720	88146	101186	107616		591840
Cum 31123251 (175 kW)				54973	48507	63474	31236	34627	24529	0	0	0		257347
Cum 31123250 (175 kW)				57363	78341	43212	33623	45956	28463	87910	100767	106608		582243
Cum 31122570 (175 kW)				57363	66271	64370	42186	39743	51604	8264	2527	2016		334345
Total kWh				215112	255404	193200	155760	170942	170317	184320	204480	216240		1765775
Site Capacity Factor ++				0.43	0.49	0.38	0.30	0.33	0.33	0.35	0.39	0.42		0.38
Typical Engine Rate #				0.57	0.65	0.51	0.40	0.52	0.66	0.67	0.80	0.82		0.61

Costs

Diesel Engine Fuel Cost	57	57		19110	21066	17698	16060	16467	15680	16524	17711	18253	17619	158569
Lube Oil Cost	0	0		161	174	63	143	95	118		5	100	110	879
Site Maintenance Cost	46	46		414	713	92	207	138	161		46	207	247	1978
Site Material Cost	0	0		310	1195	200	464	310	361		0	309	394	3149
Labor Operating Cost	46	46		414	5704	2254	2139	2139	2070	2083	2070	2139	2424	21812
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Diesel Engine Operating Cost	149	149		20429	28852	20307	19013	19149	18390	19407	19832	21008	20710	186387
Additional Heating Cost	26988	27056	29563	17418	15882	0	2705	0	0	0	0	0	4001	36005
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Total Site Energy Cost	27137	27205	29563	37847	44734	20307	21718	19149	18390	19407	19832	21008	25525	222392
Degree Days	1364	1940	1469	1245	817	979	132	14	24	43		1342	575	4596

* Site conversion status is indicated by MAR = sites after conversion, TRANS = sites during transition, and LRRS = sites before transition. The MAR equipment became fully operational in April 1985.

** Values in these columns are discussed in the text. The columns Monthly Value and Annual Value refer only to April through December.

*** Electricty demands (kW) were not reported for this site.

+ These values are calculated by assuming a higher heating value of 138700 Btu/gallon of diesel fuel.

++ These values are estimated.

This estimate is monthly kWh divided by the engine hours and by 175 kW.

ALASKAN REMOTE SITE ENERGY DATA FOR 1985

CAPE ROMANZOF - PHASE 1 *

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Monthly Value **	Annual Value **
Site Characterization Status	LRRS	TRANS	TRANS	TRANS	TRANS	TRANS	TRANS	MAR	MAR	MAR	MAR	MAR		
Fuel Consumption (Gallons)														
Engine		80	90	7155	7110	6390	10200	14675	13520	16530	18455	17945	16225	81125
Boiler								10965	10903	13260	1878		9252	37006
Total		80	90	7155	7110	6390	10200	25640	24423	29790	20333	17945	25477	118131
Electricity Production														
Generation (kWh)		1120	1280	107185	110704	88800	144240	207600	196320	246240	293760	260200	240824	1204120
Maximum Demand (kW)		160	160	166	16[illegible]	155	310	380	360	495	510	495	446	510
Average Demand (kW)		140	157	156		124	194	279	272	330	408	350	328	
Minimum Demand (kW)		130	136	132	118	115	127	260	250	290	360	300	292	250
Efficiency (kWh/gal)		14.00	14.22	14.98	15.57	13.90	14.14	14.15	14.52	14.90	15.92	14.50		14.84
Efficiency (%) +		0.34	0.35	0.37	0.38	0.34	0.[illegible]	0.35	0.36	0.37	0.39	0.36		0.37
Heat Rate (Btu/kWh) +		9907	9752	9259	8908	9981	9808	9805	9552	9311	8714	9566		9345
Operaration Parameters														
Engine Run Time (Hours)														
Cum 31128016 (175 kW)		2	2	240	118	164	262	518	0	253	479	564	363	1814
Cum 31128013 (175 kW)		2	2	241	301	1	569	257	458	379	541	605	452	2260
Cum 31128012 (175 kW)		2	2	69	47	305	111	448	464	543	643	404	500	2502
Cum 31128014 (175 kW)		2	2	138	282	255	204	303	524	630	497	555	502	2509
Engine Hours		8	8	688	748	725	1146	1526	1446	1805	2180	2128	1817	9085
Total Engine Hours														
Cum 31128016 (175 kW)		270	272	512	630	794	1056	1574	1574	1827	2306	2870		
Cum 31128013 (175 kW)		296	298	739	1040	1041	1610	1867	2325	2704	3265	3870		
Cum 31128012 (175 kW)		384	386	455	502	807	918	1366	1830	2373	3016	3420		
Cum 31128014 (175 kW)		401	403	541	823	1078	1282	1585	2109	2739	3236	3791		
Engine kWh Generation ++														
Cum 31128016 (175 kW)		280	320	37390	17464	20087	32976	70470	0	34515	64546	68963		240426
Cum 31128013 (175 kW)		280	320	37546	44548	122	71617	34963	62182	51704	75596	73976		299539
Cum 31128012 (175 kW)		280	320	10750	6956	37357	13971	60947	62996	74077	86646	49399		331613
Cum 31128014 (175 kW)		280	320	21499	41736	31233	25676	41221	71142	85945	66972	67862		332541
Total kWh		1120	1280	107185	110704	88800	144240	207600	196320	246240	293760	260200		1204120
Site Capacity Factor ++		.00	.00	0.21	0.21	0.18	0.28	0.40	0.39	0.49	[illegible].58	0.52		0.47

Typical Engine Rate	#		0.80	0.91	0.89	0.85	0.70	0.72	0.78	0.78	0.78	0.77	0.70		0.76
Site Load Factor	##		0.01	0.01	0.90	0.89	0.80	0.63	0.73	0.76	0.69	0.80	0.73	0.73	0.64
Costs															
Diesel Engine Fuel Cost			103	116	9230	9172	8243	9690	13941	12844	15703	17532	17047	15005	77067
Lube Oil Cost			0	0	171	48	171	275	321	229	321	413	367	330	1651
Site Maintenance Cost			0	0	276	92	276	552	1012	713	1012	920	920	915	4577
Site Material Cost			0	0	205	71	217	451	822	331	903	908	897	772	3861
Labor Operating Cost			184	184	276	92	1035	1679	3565	1357	2139	1380	2139	2116	10580
Diesel Engine Operating Cost			287	300	10158	9475	9942	12647	19661	15474	20078	21153	21370	19547	97736
Additional Heating Cost									10417	10358	12597	1784		8789	35156
Total Site Energy Cost			287	300	10158	9475	9942	12647	30078	25832	32675	22937	21370	26578	132892
Degree Days		1240	1240	1710	1710	992	649	230	468	730	1209	1410	1085	980	4902

* Site characterization status is indicated by MAR = sites after conversion, TRANS = siter during LRRS/MAR site transition, and LLRS = sites before transition. The MAR equipment became fully operational in August 1985.

** Values in these columns are discussed in the text.

+ These values are calculated by assuming a higher heating value of 138700 Btu/gallon of diesel fuel.

++ These values are estimated.

This estimate is monthly kWh divided by the engine hours and by 175 kW.

The monthly load factor is the kWh divided by the peak demand and by the hours in the month.

ALASKAN REMOTE SITE ENERGY DATA FOR 1985

CAPE NEWENHAM - PHASE 2A *

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Monthly Value **	Annual Value **
Site Conversion Status	MAR	MAR	MAR	MAR	MAR	MAR	MAR	MAR	MAR	MAR	MAR	MAR		
Fuel Consumption (Gallons)														
Engine	16610	14650	17020	14160	14700	13510	15440	18450	12770	13730	15438	17220	15308	183698
Boiler			900	1182	2672	1662	1595	264	3367	1847			1686	13489
Total	16610	14650	17920	15342	17372	15172	17035	18714	16137	15577	15438	17220	16994	197187
Electricity Production														
Generation (kWh)	179040	173280	195120	168720	192960	149040	174960	184560	168960	176640	191520	190080	178740	2144880
Maximum Demand (kW)	260	350	300	270	270	250	270	280	260	290	320	300	285	350
Average Demand (kW)	245	258	262	253	245	210	235	248	235	237	280	270	248	
Minimum Demand (kW)	210	230	230	220	226	207	220	230	210	220	220	250	223	207
Efficiency (kWh/gal)	10.78	11.83	11.46	11.92	13.13	11.03	11.33	10.00	13.23	12.87	12.41	11.04		11.68
Efficiency (%) +	0.27	0.29	0.28	0.29	0.32	0.27	0.28	0.25	0.33	0.32	0.31	0.27		0.29
Heat Rate (Btu/kWh) +	12868	11726	12099	11641	10566	12573	12240	13865	10483	10781	11180	12565		11879
Operaration Parameters														
Engine Run Time (Hours)														
Cat 4686094 (250kW)	259	103	0	0	0	147	312	349	541	389	510	484	258	3094
Cat 4686089 (250kW)	563	299	458	543	221	331	463	463	435	365	106	0	354	4247
Cat 4686093 (250kW)	384	431	190	500	392	130	489	400	396	524	267	1469	464	5572
Cat 4686090 (250kW)	254	149	556	474	497	217	51	346	0	217	583	539	324	3883
Engine Hours	1460	982	1204	1517	1110	825	1315	1558	1372	1495	1466	2492	1400	16796
Total Engine Hours														
Cat 4686094 (250kW)	12743	12864	12864	12864	12864	13010	13322	13671	14212	14501	15111	15595		
Cat 4686089 (250kW)	14249	14548	15006	15549	15770	16113	16576	17039	17474	17839	17945			
Cat 4686093 (250kW)	14740	15171	15190	15690	16074	16204	16693	17093	17489	18013	18280	18749		
Cat 4686090 (250kW)	14183	14329	14885	15359	15832	16049	16100	16446	16446	16663	18246	17785		
Engine kWh Generation ++														
Cat 4686094 (250kW)	28320	24480	0	0	0	26640	36480	42480	62400	45360	45360	45360		356880
Cat 4686089 (250kW)	68880	43920	81120	60480	27360	69600	54960	54000	54720	39600	39600	39600		633840
Cat 4686093 (250kW)	50160	76320	7200	56640	75360	16560	78000	44640	51840	62880	62880	62880		645360
Cat 4686090 (250kW)	31680	28560	106800	51600	90240	36240	5520	43440	0	28800	28800	28800		480480
Total kWh	179040	173280	195120	168720	192960	149040	174960	184560	168960	176640	191520	190080		2144880
Site Capacity Factor ++	0.24	0.26	0.26	0.23	0.26	0.21	0.24	0.25	0.23	0.25	0.27	0.26		0.24

Typical Engine Rate	$	0.49	0.71	0.65	0.44	0.70	0.72	0.53	0.47	0.49	0.47	0.52	0.31	.	0.51
Site Load Factor	$$	0.93	0.74	0.87	0.87	0.96	0.83	0.87	0.89	0.90	0.85	0.83	0.88	0.86	0.70
Costs															
Diesel Engine Fuel Cost		21427	18899	21956	18266	18963	17428	19918	23801	16473	17711	21517	22213	19748	236970
Lube Oil Cost		170	74	85	106	116	55	109	201	141	103	131	74	114	1365
Site Maintenance Cost		920	782	414	414	644	230	920	1012	966	828	667	391	682	8188
Site Material Cost		177	1993	129	169	163	82	1301	254	202	535	130	88	435	5223
Labor Operating Cost		2622	1288	1656	598	598	2070	2093	2139	2070	2139	2047	2139	1788	21459
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Diesel Engine Operating Cost		25316	23036	24240	19553	20484	19865	24341	27407	19852	21316	24492	24905	22900	274806
Additional Heating Cost	'			1161	1525	3447	2144	2058	341	4343	2383			2175	17401
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Total Site Energy Cost		25316	23036	25401	21078	23931	22009	26398	27747	24196	23699	24492	24905	24351	292207
Degree Days		983	1495	1333	1420	857	669	431	474	549	994	964	968	928	11137

* The site conversion status is indicated by MAR = site after conversion, TRANS = site during the LRRS/MAR site transition, and LRRS = site before conversion. The MAR equipment became fully operational in Febuary 1984. Reported fuel consumption for boiler usage was not clear for January and Febuary.

** Values in these columns are discussed in the text.

\+ These values are calculated by assuming a higher heating value of 138700 Btu/gallon of diesel fuel.

++ These values are estimated.

$ This estimate is monthly kWh divided by the engine hours and by 250 kW.

$$ The monthly load factor is the kWh divided by the peak demand and by the hours in the month.

' This refers to additional heat which is provided by boiler plants only.

ALASKAN REMOTE SITE ENERGY DATA FOR 1985

FORT YUKON - PHASE 2A *

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Monthly Value **	Annual Value **
Site Conversion Status				MAR	MAR	MAR	MAR	MAR	MAR	MAR	MAR	MAR		
Fuel Consumption (Gallons)														
Engine				5295	6360	5118	4650	5883	6116	7432	6549	7179	6065	54582
Boiler										3142	4568	4526		
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Total				5295	6360	5118	4650	5883	6116	10574	11117	11705	6065	54582
Electricity Production														
Generation (kWh)				102720	124792	65661	60982	63166	67500	91000	117136	94527	87498	787484
Maximum Demand (kW)				180	240	185	180	185	200	240	220	235	207	240
Average Demand (kW)				140	167	120	100	90	94	175	155	195	137	
Minimum Demand (kW)				80	120	110	81	84	70	122	135	155	106	70
Efficiency (kWh/gal)				19.40	19.62	12.83	13.11	10.74	11.04	12.24	17.89	13.17		14.43
Efficiency (%) +				0.48	0.48	0.32	0.32	0.26	0.27	0.30	0.44	0.32		0.35
Heat Rate (Btu/kWh) +				7150	7069	10811	10576	12918	12567	11328	7755	10588		9614
Operaration Parameters														
Engine Run Time (Hours)														
Cummins 31130706 (250kW)				69	224	206	173	118	242	32	366	396	203	1826
Cummins 31130705 (250kW)				190	168	122	251	248	133	353	91	0	173	1556
Cummins 31130704 (250kW)				249	250	253	122	155	248	18	221	0	168	1516
Cummins 31130703 (250kW)				206	153	152	221	225	101	399	187	382	225	2026
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Engine Hours				714	795	733	767	746	724	802	865	778	769	6924
Total Engine Hours														
Cummins 31130706 (250kW)				529	753	959	1132	1250	1492	1562	1928	2324		
Cummins 31130705 (250kW)				460	628	750	1001	1249	1382	1723	1814	1814		
Cummins 31130704 (250kW)				500	750	1003	1125	1280	1528	1534	1755	1755		
Cummins 31130703 (250kW)				471	624	776	997	1222	1323	1750	1937	2319		
Engine kWh Generation ++														
Cummins 31130706 (250kW)				9927	35162	18453	13755	9991	22562	1562	49563	48114		209089
Cummins 31130705 (250kW)				27334	26371	10929	19956	20999	12400	1723	12323	0		132035
Cummins 31130704 (250kW)				35623	39243	22663	9700	13124	23122	1534	29927	0		175135
Cummins 31130703 (250kW)				29636	24017	13616	17571	19051	9416	1750	25323	46413		186794
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Total kWh				102720	124792	65661	60982	63166	67500	91000	117136	94527		787484
Site Capacity Factor ++				0.14	0.17	0.09	0.08	0.08	0.09	0.13	0.16	0.13		0.12

Typical Engine Rate #				0.58	0.63	0.36	0.32	0.34	0.37	0.45	0.54	0.49	.	0.45
Site Load Factor ##				0.79	0.70	0.49	0.46	0.46	0.47	0.53	0.74	0.56	0.58	0.50
Costs														
Diesel Engine Fuel Cost				6831	8204	6602	5999	7589	7889	9587	8448	8448	7823	70411
Lube Oil Cost				32	63	45	44	43	46	33	50	59	46	415
Site Maintenance Cost				230	368	345	345	391	345	230	345	460	340	3059
Site Material Cost				153	268	201	230	119	229	153	229	306	210	1888
Labor Operating Cost				2760	2139	2254	1794	1886	1334	2806	1955	2231	2129	19159
Diesel Engine Operating Cost				10006	11042	9447	8412	10028	9843	12809	11027	11504	10458	94118
Additional Heating Cost '													0	0
Total Site Energy Cost				10006	11042	9447	8412	10028	9843	12809	11027	11504	10458	94118
Degree Days				1235	1180	71	50	289	730	1495			721	5050

* The site conversion status is indicated by MAR = after site conversion, TRANS = during LRRS/MAR site transition, and LRRS = before conversion. The MAR equipment became fully operational in April 1985. Heating data is not included in this spreadsheet.

** Values in these columns are discussed in the text. The annual vaules refer to data through September 1985.

+ These values are calculated by assuming a higher heating value of 138700 Btu/gallon of diesel fuel.

++ These values are estimated.

This estimate is monthly kWh divided by the engine hours and by 250 kW.

The monthly load factor is the kWh divided by the peak demand and by the hours in the month.

' This refers to additional heat which is provided by boiler plants only.

ALASKAN REMOTE SITE ENERGY DATA FOR 1985

FORT YUKON - PHASE 2A *

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Monthly Value **	Annual Value **
Site Conversion Status		LRRS	LRRS	LRRS										
Fuel Consumption (Gallons)														
Engine		20046	16682	13267									16665	49995
Boiler		2949	20305	18792									14015	42046
Total		22995	36987	32059									30680	92041
Electricity Production														
Generation (kWh)		236200	199590	163020									199603	598810
Maximum Demand (kW)		465	380	300									382	465
Average Demand (kW)		351	268	226									282	
Minimum Demand (kW)		270	200	85									185	85
Efficiency (kWh/gal)		11.78	11.96	12.29										11.98
Efficiency (%) *		0.29	0.29	0.30										0.29
Heat Rate (Btu/kWh) *		11771	11593	11288										11580
Operaration Parameters														
Engine Run Time (Hours)														
Cummins 950660 (200kW)		53	0	0									18	53
Cummins 95699 (200kW)		155	550	47									251	752
Cummins 91481 (200kW)		36	22	120									59	178
Cummins 84538 (200kW)		0	0	0									0	0
Cummins 85913 (200kW)		575	424	297									432	1296
Cummins 90526 (200kW)		238	62	167									156	467
Cummins 95701 (200kW)		0	0	0									0	0
Cummins 83653 (200kW)		129	19	300									149	448
Cummins 198396 (200kW)		440	300	300									347	1040
Cummins 90529 (200kW)		385	215	0									200	600
Herr. 3412640 (30kW)		1	2	2									2	5
Engine Hours		2012	1594	1233									1613	4839
Total Engine Hours														
Cummins 950660 (200kW)		88453	88453	88453										
Cummins 95699 (200kW)		87403	87953	88000										
Cummins 91481 (200kW)		89936	89958	90078										
Cummins 84538 (200kW)		79400	79400	79400										
Cummins 85913 (200kW)		89663	90087	90384										
Cummins 90526 (200kW)		88038	88100	88267										
Cummins 95701 (200kW)		64334	64334	64334										
Cummins 83653 (200kW)		94781	94800	95100										

Cummins 198396 (200kW)	87300	87600	87900		
Cummins 90529 (200kW)	90685	90900	90900		
Herr. 3412640 (30kW)	496	498	500		
Engine kWh Generation ++					
Cummins 950660 (200kW)	6222	0	0		6222
Cummins 95699 (200kW)	18196	68867	6214		93278
Cummins 91481 (200kW)	4226	2755	15866		22847
Cummins 84538 (200kW)	0	0	0		0
Cummins 85913 (200kW)	67502	53090	39268		159861
Cummins 90526 (200kW)	27940	7763	22080		57783
Cummins 95701 (200kW)	0	0	0		0
Cummins 83653 (200kW)	15144	2379	39664		57187
Cummins 198396 (200kW)	51654	37564	39664		128882
Cummins 90529 (200kW)	45197	26921	0		72118
Herr. 3412640 (30kW)	117	250	264		632
Total kWh	236200	199590	163020		598810
Site Capacity Factor ++	0.17	0.13	0.11		0.14
Typical Engine Rate #	0.59	0.63	0.66		0.49
Site Load Factor ##	0.76	0.71	0.75	0.73	0.60
Costs					
Diesel Engine Fuel Cost	25859	21520	17114	21498	64494
Lube Oil Cost	360	397	258	338	1015
Site Maintenance Cost	1610	1406	782	1266	3798
Site Material Cost	364	433	216	338	1013
Labor Operating Cost	15456	15628	15755	15613	46839
Diesel Engine Operating Cost	43649	39384	34125	39053	117159
Additional Heating Cost +	3804	26193	24242	18080	54239
Total Site Energy Cost	47454	65577	58367	57133	171398
Degree Days	2178	1433	1235	1615	4846

\# The site conversion status is indicated by MAR = site after conversion, TRANS = site during the LRRS/MAR site transition, ans LRRS = site befor conversion. The MAR equipment became operational in April 1985. The data in this spreadsheet refers to the LRRS.

\## Values in these columns are discussed in the text. The annual values refer to data from Febuary through April 1985.

\+ These values are calculated by assuming a higher heating value of 138700 Btu/gallon of diesel fuel.

++ These values are estimated.

This estimate is monthly kWh that was generated by the Cummins type engines divided by the engine hours and by 200 kW.

The monthly load factor is the kWh divided by the peak demand and by the hours in the month.

' This refers to additional heat which is provided by boiler plants only.

ALASKAN REMOTE SITE ENERGY DATA FOR 1985

CAPE LISBURNE - PHASE 2A *

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Monthly Value **	Annual Value **
Site Conversion Status	LRRS	LRRS	LRRS	LRRS	LRRS	LRRS	LRRS	LRRS	LRRS	LRRS	LRRS	LRRS		
Fuel Consumption (Gallons)														
Engine	23080	21713	23080	21340	18720	18810	19460	18447	18025	20920	21204	18940	20312	243739
Boiler	22834	22586	23610	21151	13309	9193	4745	5893	12443	21847	20786	21080	16623	199477
Total	45914	44299	46690	42491	32029	28003	24205	24340	30468	42767	41990	40020	36935	443216
Electricity Production														
Generation (kWh)	283776	258816	293376	250796	203904	215524	216960	223488	221184	267264	256128	261120	246028	2952336
Maximum Demand (kW)	426	426	426	399	332	332	332	612	350	405	372	380	399	612
Average Demand (kW)	380	418	379	340	286	299	292	300	320	360	356	360	341	
Minimum Demand (kW)	292	266	332	280	240	254	254	254	270	283	297	290	339	240
Efficiency (kWh/gal)	12.30	11.92	12.71	11.75	10.89	11.46	11.15	12.12	12.27	12.80	12.00	12.00		12.11
Efficiency (%) +	0.30	0.29	0.31	0.29	0.27	0.28	0.27	0.30	0.30	0.31	0.30	0.30		0.30
Heat Rate (Btu/kWh) +	11281	11636	10912	11802	12734	12105	12441	11448	11303	10836	11558	11558		11451
Operaration Parameters														
Engine Run Time (Hours)														
CP 82628 (350kW)	128	372	113	0	5	377	461	294	432	581	413	692	322	3868
CP 82632 (350kW)	697	576	632	633	383	210	400	501	342	384	582	302	470	5642
CP 82631 (350kW)	283	280	421	59	294	339	287	667	666	524	360	384	380	4564
CP 82629 (350kW)	517	116	302	221	361	500	323	36	0	0	0	0	198	2376
CP 82630 (350kW)	0	0	0	525	723	4	0	0	0	0	0	0	104	1252
Engine Hours	1625	1344	1468	1438	1766	1430	1471	1498	1440	1489	1355	1378	1475	17702
Total Engine Hours														
CP 82628 (350kW)	50396	50768	50881	50881	50886	51263	51724	52018	52450	53031	53444	54136		
CP 82632 (350kW)	52834	53415	54047	54680	55063	55273	55673	56174	56516	56900	57482	57784		
CP 82631 (350kW)	51647	51927	52348	52431	52725	53064	53351	54018	54684	55208	55568	55952		
CP 82629 (350kW)	52864	52980	53282	53503	53864	54364	54687	54723	****	0	0	0		
CP 82630 (350kW)	54625	53616	53616	54141	54567	54571	54571	54571	54571	0	0	0		
Engine kWh Generation **														
CP 82628 (350kW)	22353	71637	22583	0	577	56820	67994	43862	66355	104285	78067	131128		665661
CP 82632 (350kW)	121718	110921	126304	110399	44222	31650	58997	74745	52531	68925	110012	57227		967650
CP 82631 (350kW)	49421	53920	84136	10290	33946	51093	42330	99510	102298	94054	68049	72765		761810
CP 82629 (350kW)	90284	22338	60354	38544	41681	75358	47640	5371	0	0	0	0		381570
CP 82630 (350kW)	0	0	0	91563	83478	603	0	0	0	0	0	0		175644
Total kWh	283776	258816	293376	250796	203904	215524	216960	223488	221184	267264	256128	261120		2952336

Site Capacity Factor	++	0.22	0.22	0.23	0.20	0.16	0.17	0.17	0.17	0.18	0.21	0.20	0.21		0.19
Typical Engine Rate	#	0.50	0.55	0.57	0.50	0.33	0.43	0.42	0.43	0.44	0.51	0.54	0.54		0.48
Site Load Factor	##	0.90	0.90	0.93	0.87	0.83	0.90	0.88	0.49	0.88	0.92	0.96	0.95	0.84	0.55
Costs															
Diesel Engine Fuel Cost		29773	28010	29773	27529	24149	24265	25103	23797	23252	26986	27353	24432	26202	314423
Lube Oil Cost		317	341	101	327	196	243	193	143	212	165	321	50	217	2609
Site Maintenance Cost		460	828	621	828	920	1392	483	828	920	1104	598	368	779	9350
Site Material Cost		862	383	973		750	2345	925	691	383	68861	255	255	6971	76683
Labor Operating Cost		12834	14628	14973	15180	14260	14260	12834	8556	12742	12121	12972	12558	13160	157918
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Diesel Engine Operating Cost		44246	44190	46441	43864	40275	42505	39538	34015	37509	109237	41499	37663	46748	560981
Additional Heating Cost	!	29456	29136	30457	27285	17169	11859	6121	7602	16051	28183	26814	27193	21444	257325
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Total Site Energy Cost		73702	73326	76898	71148	57443	54364	45659	41617	53561	137420	68313	64856	68192	818307
Degree Days		1913	1449	1864	2123	1126	702	433						1373	9610

* The site conversion status is indicated by MAR = after site conversion, TRANS = during LRRS/MAR site transition, and LRRS = sites before conversion. The MAR equipment is scheduled to be installed sometime after 1985.

** Values in these columns are discussed in text.

\+ These values are calculated by assuming a higher heating value of 138700 Btu/gallon of diesel fuel.

++ These values are estimated.

\# This estimate is monthly kWh divided by the engine hours and by 350 kW.

\#\# The monthly load factor is the kWh divided by the peak demand and by the hours in the month.

! This refers to additional heat which is provided by boiler plants only.

ALASKAN REMOTE SITE ENERGY DATA FOR 1985

TIN CITY - PHASE 2A *

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Monthly Value **	Annual Value **
Site Conversion Status	LRRS	LRRS	LRRS	LRRS	LRRS	LRRS	LRRS	LRRS	LRRS	LRRS	LRRS	LRRS		
Fuel Consumption (Gallons)														
Engine	21477	21425	21887	21081	18611	16666	16404	17540	17650	21309	19900	20293	19520	234243
Boiler	16129	19453	18328	12563	19497	21931	7862	8012	13521		17900	21817	16092	177013
Total	37606	40878	40215	33644	38108	38597	24266	25552	31171		37800	42110	35612	411256
Electricity Production														
Generation (kWh)	244029	216198	257935	252974	215493	190109	193151	196339	201553	242706	227115	229654	222271	2667256
Maximum Demand (kW)	403	443	406	432	379	321	320	316		402	388	394	382	443
Average Demand (kW)	328	364	347	352	290	264	260	264		326	315	308	311	
Minimum Demand (kW)	272	305	274	304	226	224	220	218		185	266	247	249	185
Efficiency (kWh/gal)	11.36	10.09	11.78	12.00	11.58	11.41	11.77	11.19	11.42	11.39	11.41	11.32		11.39
Efficiency (%) *	0.28	0.25	0.29	0.30	0.28	0.28	0.29	0.28	0.28	0.28	0.28	0.28		0.28
Heat Rate (Btu/kWh) *	12207	13745	11769	11558	11979	12159	11780	12391	12146	12178	12153	12256		12181
Operaration Parameters														
Engine Run Time (Hours)														
Cummins 91488 (100kW)	503	397	448	27	425	11	2	438	0	450	0	10	226	2711
Cummins 135985 (100kW)	440	400	637	432	205	668	512	231	379	148	569	501	427	5122
Cummins 91990 (100kW)	0	445	110	517	280	0	20	427	307	572	587	584	321	3849
Cummins 135989 (100kW)	97	0	0	0	0	0	0	0	0	0	4	233	28	334
Cummins 100027 (100kW)	635	156	395	643	0	0	0	1	74	300	537	495	270	3236
Cummins 131165 (100kW)	631	428	22	64	431	691	433	626	313	628	425	321	418	5013
Cummins 91489 (100kW)	0	360	540	417	450	450	306	144	546	551	0	0	314	3764
Cummins 007 (100kW)	298	586	18	590	,707	199	693	459	166	8	4	0	311	3728
Cummins 90527 (100kW)	395	138	450	436	97	344	92	288	34	269	316	570	286	3429
Cummins 91490 (100kW)	310	94	243	345	328	479	450	450	450	212	213	32	301	3606
Cummins 91486 (100kW)	349	554	603	118	20	47	740	73	581	336	433	450	359	4304
Engine Hours	3658	3558	3466	3589	2943	2889	3248	3137	2850	3474	3088	3196	3258	39096
Total Engine Hours														
Cummins 91488 (100kW)	121880	122277	122725	122752	123177	123188	123190	123628	123628	124078	124078	124088		
Cummins 135985 (100kW)	124076	124476	125113	125545	125750	126418	126930	127161	127540	127688	128257	128758		
Cummins 91990 (100kW)	115354	115799	115909	116426	116706	116706	116726	117153	117460	118032	118619	119203		
Cummins 135989 (100kW)	126480	126480	126480	126480	126480	126480	126480	126480	126480	126480	126484	126717		
Cummins 100027 (100kW)	124595	124751	125146	125789	125789	125789	125789	125790	125864	126164	126701	127196		
Cummins 131165 (100kW)	121205	121633	121655	121719	122150	122841	123274	133900	124213	124841	125266	125587		
Cummins 91489 (100kW)	123840	124200	124740	125157	125607	126057	126363	126507	127053	127604	127604	127604		
Cummins 007 (100kW)	120904	121490	121508	122098	122805	123004	123697	124156	124322	124330	124334	124334		

Cummins 90527 (100kW)	124959	125097	125547	125983	126080	126424	126516	126804	126838	127107	127423	127993		
Cummins 91490 (100kW)	68263	68357	68600	68945	69273	69752	70202	70652	71102	71314	71527	71559		
Cummins 91486 (100kW)	117040	117594	118197	118315	118335	118382	119122	119195	119776	120112	120545	120995		
Engine kWh Generation ++														
Cummins 91488 (100kW)	33556	24123	33340	1903	31119	724	119	27414	0	31439	0	719		184455
Cummins 135985 (100kW)	29353	24306	47405	30450	15011	43957	30447	14458	26803	10340	41849	36000		350378
Cummins 91990 (100kW)	0	27040	8186	36441	20502	0	1189	26725	21711	39962	43172	41964		266894
Cummins 135989 (100kW)	6471	0	0	0	0	0	0	0	0	[illegible]	294	16743		23508
Cummins 100027 (100kW)	42362	9479	29395	45322	0	0	0	63	5233	20959	39495	55569		227878
Cummins 131165 (100kW)	42095	26007	1637	4511	31559	45471	25750	39180	22135	43874	31258	23066		336543
Cummins 91489 (100kW)	0	21875	40186	29393	32950	29612	18197	9013	38613	38495	0	0		258334
Cummins 007 (100kW)	19880	35606	1340	41587	51768	13095	41211	28728	11740	559	294	0		245809
Cummins 90527 (100kW)	26351	8385	33488	30732	7103	22637	5471	18025	2404	18793	23241	40958		237589
Cummins 91490 (100kW)	20680	5712	18084	24318	24017	31520	26760	28165	31824	14811	15666	2299		243856
Cummins 91486 (100kW)	23282	33663	44874	8317	1464	3093	44006	4569	41089	23474	31846	32336		292014
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Total kWh	244029	216198	257935	252974	215493	190109	193151	196339	201553	242706	227115	229654		2667256
Site Capacity Factor ++	0.30	0.29	0.32	0.32	0.26	0.24	0.24	0.24	0.25	0.30	0.29	0.28		0.28
Typical Engine Rate #	0.67	0.61	0.74	0.70	0.73	0.66	0.59	0.63	0.71	0.70	0.74	0.72		0.68
Site Load Factor ##	0.81	0.73	0.85	0.81	0.76	0.82	0.81	0.84	ERR	0.81	0.79	0.78	0.80	0.69
Costs														
Diesel Engine Fuel Cost	27705	27638	28234	27194	24008	21499	21161	22627	22769	22768	25445	26177	25181	302173
Lube Oil Cost	377	405	562	346	449	417		424	459	240	309	536	411	4524
Site Maintenance Cost	2530	1633	2699	2806	2645	2280	92	2323	2645	2081	1702	2921	2196	26357
Site Material Cost	5175	496	5221	1597	1894	1145	731	2480	9764	3233	2456	258	2870	34444
Labor Operating Cost	19826	21275	21413	17296	21919	22084	21758	21413	21367	22482	23138	21643	21301	255614
	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-- --	-----
Diesel Engine Operating Cost	55613	51441	58129	49239	50915	47425	43742	49267	57004	50804	53050	51535	51514	618165
Additional Heating Cost '	20806	25094	23643	16206	25151	28291	10142	10335	17442	0	23091	28144	20759	228347
	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Total Site Energy Cost	76420	76536	81772	65446	76066	75716	53884	59602	74446	50804	76141	79679	70543	846512
Degree Days	1534	1740	2014	1940	1116	750	346	320	632	953	2436	1418	1267	15199
Emergency Back-up Units														
Fuel Consumption (Gallons)					3297	2160	2262	2227	2151	1938	1368			15399
Generation (kWh)					25277	16560	17473	17043	16491	11140	4560			108544
Efficiency (kWh/gal)					7.67	7.67	7.72	7.67	7.67	5.75	3.33			7.05
Efficiency (%) +					0.19	0.19	0.19	0.19	0.19	0.14	0.08			0.17
Heat Rate (Btu/kWh) +					18091	18091	17956	18091	18091	24129	41610			19677

Operaration Parameters

Engine Run Time (Hours)								
GMC 670162 (63kW)	1099	720	717	741	717	360	0	4354
GMC 670165 (63kW)	0	0	27	0	0	0	0	27
GMC 6459607 (200kW)	0	0	6	0	0	0	0	6
Bogue 6505361 (56kW)	0	0	0	0	0	286	456	742
	-----	-----	-----	-----	-----	-----	-----	-----
Engine Hours	1099	720	750	741	717	646	456	5129
Total Engine Hours								
GMC 670162 (63kW)	11769	12489	13206	13947	14664	15024	15024	
GMC 670165 (63kW)	36265	36265	36532	36532	36532	36532	36532	
GMC 6459607 (200kW)	178	178	184	184	184	184	184	
Bogue 6505361 (56kW)	1072	1072	1072	1072	1072	1357	1813	
Engine kWh Generation ++								
GMC 670162 (63kW)	25277	16560	16491	17043	16491	8280	0	100142
GMC 670165 (63kW)	0	0	616	0	0	0	0	616
GMC 6459607 (200kW)	0	0	366	0	0	0	0	366
Bogue 6505361 (56kW)	0	0	0	0	0	2860	4560	7420
	-----	-----	-----	-----	-----	-----	-----	-----
Total kWh	25277	16560	17473	17043	16491	11140	4560	108544
Emergency Unit Capacity Factor ++	0.09	0.06	0.06	0.06	0.06	0.04	0.02	
Costs								
Emergency Engine Fuel Cost	4253	2786	2918	2867	2774	2500	1764	19862
Maintenance Cost	46	57	92	69	92	230	46	632
Material Cost	15	22	11	6	11	25	8	98
	-----	-----	-----	-----	-----	-----	-----	-----
Emergency Engine Operating Cost	4314	2865	3021	2942	2877	2755	1818	20592

* The site conversion status is indicated by MAR = sites after conversion, TRANS = sites during LRRS/MAR site transition, and LRRS = sites before conversion. The MAR equipment will be installed in Summer 1986. Engine failure made it neccessary to use emergency back-up generators during May through November.

** Values in these columns are discussed in the text.

+ These values are calculated by assuming a higher heating value of 138700 Btu/gallon of diesel fuel.

++ These values are estimated.

This estimate is monthly kWh divided by the engine hours and by 100 kW.

The monthly load factor is the kWh divided by the peak demand and by the hours in the month.

' This refers to additional heat which is provided by boiler plants only.

Appendix E

Life Cycle Cost Model
Test Case

```
LIFE CYCLE COST MODEL                                        05/06/86 15:46

                                PRIMARY MENU

                      F1 DDD Edit Input Data
                      F2 DDD Read Existing Input Data File
                      F3 DDD Save Input Data in a File

                      F4 DDD Perform Analysis
                      F6 DDD Queue File To Printer (Via DOS)

                      F9 DDD Directory

                     F10 DDD Exit




              Press Function Key To Select Desired Action
```

```
LIFE CYCLE COST MODEL                                        05/06/86 15:46

                                REPORT TITLE

<GENERIC ALASKAN REMOTE SITE                                                >


                             SYSTEM DESCRIPTION

          Prime Mover(s)           CUMMINS ENGINE
          Number of Units                            4 Units
          Electric Capacity                      250.0 kW/Unit
          Thermal Capacity                      3200.0 Btu/HP
          Generator capacity factor               80.0 %
          Total Boiler Capacity                    2.8 MMBtu/Hr
          Boiler Efficiency                       80.0 %
          Fuel Higher Heating Value           138700.0 Btu/Gal
          Basic Fuel Cost                          1.5 $/Gal
          Lube Oil Cost                            4.7 $/Gal

                        F8=Next Screen  F10=Return
```

LIFE CYCLE COST MODEL 05/06/86 15:47

INFLATION RATES

Consumer Prices	6.0 %
Fuel Prices	6.0 %
Electricity	6.0 %
Discount Rate	6.0 %

F7=Previous Screen F8=Next Screen F10=Return

LIFE CYCLE COST MODEL 05/06/86 15:47

INSTALLATION COST

Detail Installation Cost	N
Total Installation Cost	886000.0 $
In-house Labor Rate(1)	0.0 $/Hr
In-House Labor Hour(1)	0.0 Hr
Contractor Labor Rate(1)	0.0 $/Hr
Contractor Labor Hour(1)	0.0 Hr
In-house Labor Rate(2)	0.0 $/Hr
In-House Labor Hour(2)	0.0 Hr
Contractor Labor Rate(2)	0.0 $/Hr
Contractor Labor Hour(2)	0.0 Hr

F7=Previous Screen F8=Next Screen F10=Return

LIFE CYCLE COST MODEL 05/06/86 15:47

INSTALLATION COST

Detail Transportation cost	Y	
Total Transportation cost	0.0	$
AIR TRANSPORTATION		
Equipment Transportation Rate	0.0	$/Mile
Equipment Transportation Distance	0.0	Mile
Personal Transportation Rate	0.0	$/Mile
Personal Transportation Distance	0.0	Mile
WATER TRANSPORTATION		
Equipment Transportation Rate	0.0	$/Mile
Equipment Transportation Distance	0.0	Mile
Personal Transportation Rate	0.0	$/Mile
Personal Transportation Distance	0.0	Mile
GROUND TRANSPORTATION		
Equipment Transportation Rate	0.0	$/Mile
Equipment Transportation Distance	0.0	Mile
Personal Transportation Rate	0.0	$/Mile
Personal Transportation Distance	0.0	Mile

F7=Previous Screen F8=Next Screen F10=Return

LIFE CYCLE COST MODEL 05/06/86 15:47

INSTALLATION COST

EQUIPMENT COST

Major Equipment		Other Material	
1)	100	1)	100
2)	100	2)	100
3)	100	3)	100
4)	100	4)	100
5)	100	5)	100
6)	100	6)	100
7)	100	7)	100
8)	100	8)	100
9)	100	9)	100
10)	100	10)	100

F7=Previous Screen F8=Next Screen F10=Return

LIFE CYCLE COST MODEL 05/06/86 15:47

OPERATION AND MAINTENANCE COST

Detail Maintenance Cost		N
Total Maintenance Cost	48400.0	\$/Yr

SCHEDULED

Parts	0.0	\$/Yr
Parts Transportation Cost	0.0	\$/Yr
In-house Labor Hour	0.0	Hr/Yr
Contractor Labor Hour	0.0	Hr/Yr

UNSCHEDULED

Parts	0.0	\$/Yr
Parts Transportation Cost	0.0	\$/Yr
In-house Labor Hour	0.0	Hr/Yr
Contractor Labor Hour	0.0	Hr/Yr
Overhead/Fee	0	%

F7=Previous Screen F8=Next Screen F10=Return

LIFE CYCLE COST MODEL 05/06/86 15:48

SCHEDULE

Construction Start Date:	Month 1 Year 1986
On-Line Date	Month 1 Year 1987
Number of Years Analyzed	20 Years

F7=Previous Screen F8=Next Screen F10=Return

LIFE CYCLE COST MODEL 05/06/86 15:48

OIL CONSUMPTION AND MONTHLY THERMAL LOAD

	Lube Oil (Gal)	Thermal Load (MMBtu)
January	25.	1650.
Febuary	25.	1400.
March	25.	1050.
April	25.	650.0
May	30.	200.0
June	30.	0.0
July	28.	0.0
August	28.	200.0
September	25.	650.0
October	25.	1050.
November	27.	1400.
December	26.	1650.

F7=Previous Screen F8=Next Screen F10=Return

LIFE CYCLE COST MODEL 05/06/86 15:49

ELECTRIC LOAD PROFILE
Morning Hours

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1 AM	275	275	275	275	275	275	275	275	275	275	275	275
2 AM	275	275	275	275	275	275	275	275	275	275	275	275
3 AM	275	275	275	275	275	275	275	275	275	275	275	275
4 AM	275	275	275	275	275	275	275	275	275	275	275	275
5 AM	300	300	300	300	300	300	300	300	300	300	300	300
6 AM	300	300	300	300	300	300	300	300	300	300	300	300
7 AM	300	300	300	300	300	300	300	300	300	300	300	300
8 AM	300	300	300	300	300	300	300	300	300	300	300	300
9 AM	300	300	300	300	300	300	300	300	300	300	300	300
10 AM	300	300	300	300	300	300	300	300	300	300	300	300
11 AM	350	350	350	350	350	350	350	350	350	350	350	350
12 AM	350	350	350	350	350	350	350	350	350	350	350	350

F7=Previous Screen F8=Next Screen F10=Return

LIFE CYCLE COST MODEL 05/06/86 15:49

ELECTRIC LOAD PROFILE
Afternoon Hours

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1 PM	350	350	350	350	350	350	350	350	350	350	350	350
2 PM	300	300	300	300	300	300	300	300	300	300	300	300
3 PM	300	300	300	300	300	300	300	300	300	300	300	300
4 PM	300	300	300	300	300	300	300	300	300	300	300	300
5 PM	300	300	300	300	300	300	300	300	300	300	300	300
6 PM	300	300	300	300	300	300	300	300	300	300	300	300
7 PM	300	300	300	300	300	300	300	300	300	300	300	300
8 PM	300	300	300	300	300	300	300	300	300	300	300	300
9 PM	275	275	275	275	275	275	275	275	275	275	275	275
10 PM	275	275	275	275	275	275	275	275	275	275	275	275
11 PM	275	275	275	275	275	275	275	275	275	275	275	275
12 PM	275	275	275	275	275	275	275	275	275	275	275	275

F7=Previous Screen F8=Next Screen F10=Return

LIFE CYCLE COST MODEL 05/06/86 15:49

THERMAL VS ELECTRICAL OUTPUT

Thermal Output (Btu/hr)	Electrical Output (kW)
1) 1076716	1) 250.
2) 861373.	2) 200.
3)	3)

FUEL VS ELECTRICAL OUTPUT

Fuel consumption (Gallon/Hr)	Electrical Output (kW)
1) 16.40	1) 250.0
2) 13.20	2) 188.0
3) 9.	3) 125.0

F7=Previous Screen F10=Return

LIFE CYCLE COST ANALYSIS MODEL

GENERIC ALASKAN REMOTE SITE

SYSTEM DESCRIPTION		
Prime mover(s)	CUMMINS ENGINE	
Number of generators	4	Units
Electrical capacity	250	kW
Engine capacity factor	80	%
Boiler thermal capacity	2.8	MMBtu/hr
Boiler Efficiency	80	%
Years of analysis	20	Years
Basic fuel cost	1.5	$/GAL
Basic oil cost	4.7	$/GAL
Installation cost	886000	$
Discount Rate	6	%
Construction start date	1/1986	
On-Line date	1/1987	
INFLATION RATES		
Consumer	6	%
Fuel	6	%
Electricity	6	%

DATE: 05-06-86 PAGE: 2

LIFE CYCLE COST ANALYSIS MODEL

GENERIC ALASKAN REMOTE SITE

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
FUEL CONSUMPTION												
Engine (Gal)	15913	14886	15913	15400	15913	15400	15913	15913	15400	15913	15400	15913
Boiler (Gal)	6267	4569	860	0	0	0	0	0	0	860	4291	6267
Total Fuel Consumption (Gal)	22180	19455	16773	15400	15913	15400	15913	15913	15400	16773	19691	22180
ENERGY PRODUCTION												
Electricity (kWh)	221650	207350	221650	214500	221650	214500	221650	221650	214500	221650	214500	221650
Thermal (MMBtu)	1650	1400	1050	650	200	0	0	200	650	1050	1400	1650
FUEL COST												
Generator Fuel Cost ($)	23870	22330	23870	23100	23870	23100	23870	23870	23100	23870	23100	23870
Boiler Fuel Cost ($)	9400	6853	1289	0	0	0	0	0	0	1289	6437	9400
Total Fuel Cost ($)	33270	29183	25159	23100	23870	23100	23870	23870	23100	25159	29537	33270

LIFE CYCLE COST ANALYSIS MODEL

GENERIC ALASKAN REMOTE SITE

Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Fuel Cost ($)	316487	335476	355605	376941	399558	423531	448943	475879	504432	534698	566780	600787
Maintenance Cost ($)	48400	51304	54382	57645	61104	64770	68656	72776	77142	81771	86677	91878
Cash Investment ($)	886000	0	0	0	0	0	0	0	0	0	0	0
Net Cash Flow ($)	1250887	386780	409986	434586	460661	488301	517598	548655	581574	616469	653456	692664
Cumulative Cashflow (1000 $)	1251	1638	2048	2482	2943	3431	3949	4497	5079	5695	6349	7042
Discounted Cashflow ($)	1250887	364886	364886	364886	364886	364887	364886	364887	364886	364887	364886	364886
Cum. Dis. Cashflow (1000 $)	1251	1616	1981	2346	2710	3075	3440	3805	4170	4535	4900	5265

LIFE CYCLE COST ANALYSIS MODEL

GENERIC ALASKAN REMOTE SITE

Year	1999	2000	2001	2002	2003	2004	2005	2006	0
Fuel Cost ($)	636834	675044	715546	758479	803988	852227	903361	957562	0
Maintenance Cost ($)	97390	103234	109428	115993	122953	130330	138150	146439	0
Cash Investment ($)	0	0	0	0	0	0	0	0	0
Net Cash Flow ($)	734223	778277	824974	874472	926940	982557	1041510	1104001	0
Cumulative Cashflow (1000 $)	7776	8554	9379	10254	11181	12163	13205	14309	0
Discounted Cashflow ($)	364886	364886	364887	364886	364886	364887	364886	364887	0
Cum. Dis. Cashflow (1000 $)	5630	5994	6359	6724	7089	7454	7819	8184	0

NET PRESENT VALUE $ 8183727

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